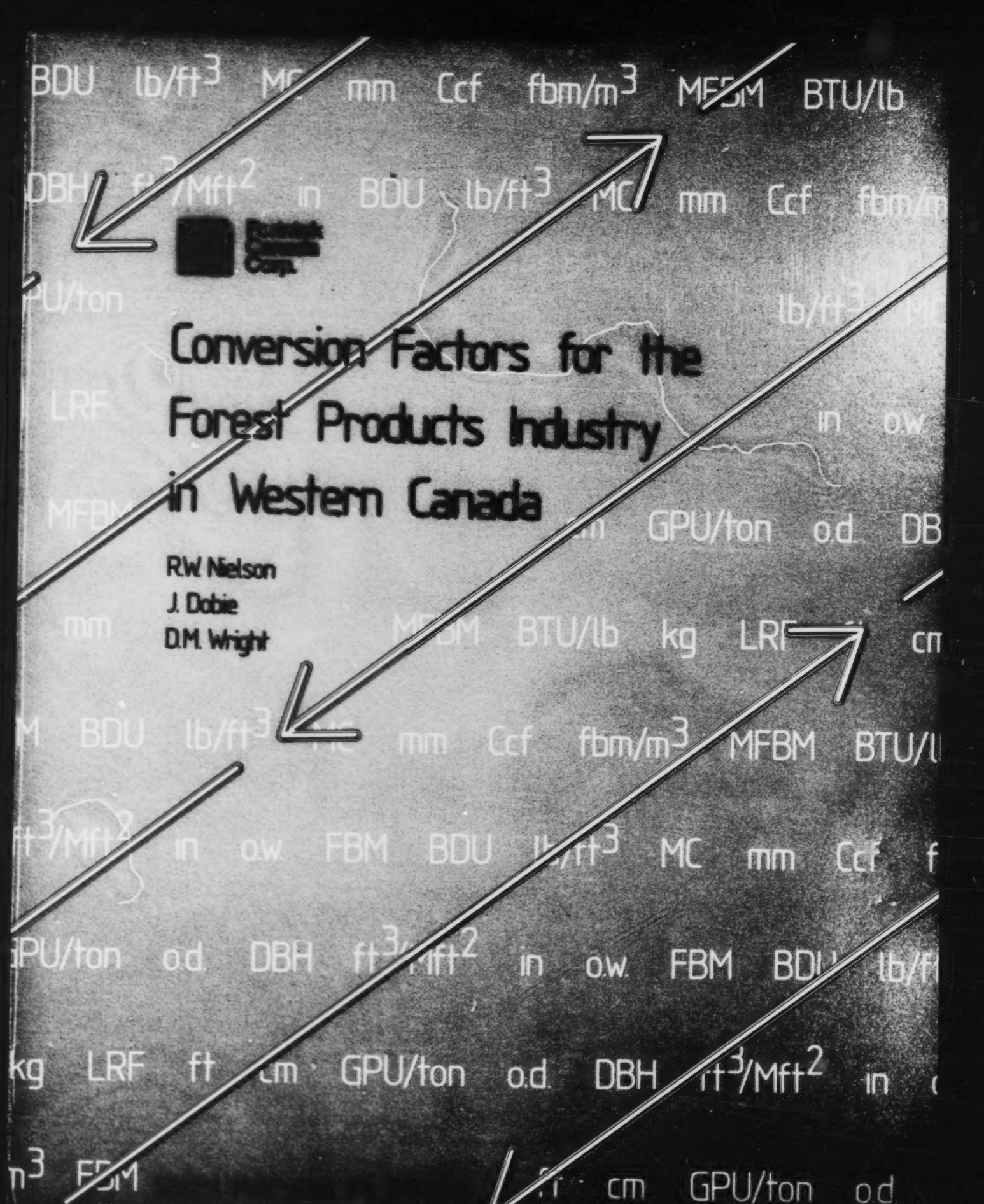
BDU lb/ft3 MC mm Ccf fbm/m3 MFBM BTU/lb
DBH ft3/Mft2 in BDU lb/ft3 MC mm Ccf
PU/ton
lb/ft3
LRF
in o.w.
MFBM
GPU/ton o.d. DB
mm
MFBM BTU/lb kg LRF cm
M BDU lb/ft3 mm Ccf fbm/m3 MFBM BTU/l
ft3/Mft2 in o.w. FBM BDU lb/ft3 MC mm Ccf f
PU/ton o.d. DBH ft3/Mft2 in o.w. FBM BDU lb/f
kg LRF ft cm GPU/ton o.d. DBH ft3/Mft2 in
m3 FBM
cm GPU/ton o.d

Conversion Factors for the Forest Products Industry in Western Canada

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CONVERSION FACTORS FOR THE FOREST PRODUCTS INDUSTRY IN WESTERN CANADA

by

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LIST OF ABBREVIATIONS

Ave.	average
BDU	bone-dry unit
Ccf	cunit
cm	centimetre
CSA	Canadian Standards Association
DBH	diameter at breast height
DBT	double-bark thickness
DIB	diameter inside bark
DOB	diameter outside bark
fbm	foot board measure
ft	foot
ft^2	square foot
ft^3	cubic foot
GPU	gravity-packed unit
in	inch
kg	kilogram
lb	pound
LRF	lumber recovery factor
m	metre
m^2	square metre
m^3	cubic metre
max.	maximum
MC	moisture content
MDF	medium density fiberboard
Mfbm	thousand board feet
min.	minimum
MJ	megajoule
mm	millimetre
No.	number
o.d.	oven-dry
o.w.	original-weight
OSB	oriented strandboard
SWE	solid wood equivalent
Vol.	volume

CONVERSION FACTORS

FOR THE FOREST PRODUCTS INDUSTRY

IN WESTERN CANADA

INTRODUCTION

This edition of "Conversion Factors" replaces earlier versions first published by the Western Forest Products Laboratory of the Canadian Forestry Service in 1972 as Information Report VP-X-97, and later revised in 1975, and Metric Conversion Factors for Forest Products in Western Canada, Technical Report No. 1 published by Forintek Canada Corp. in 1979. This new edition updates the information previously presented, and includes both metric and imperial units. The official adoption of metric log scaling practices in Canada has made substantial changes necessary to the section on Log Volume Factors. It has also led to the use of mixed metric/imperial conversion factors in industry sectors which sell products in imperial measure.

In many cases, the factors presented in this report are either average values or rough estimates, but often this level of accuracy is sufficient for the purpose at hand.

Where precise estimates are critical in decision making, it is suggested that appropriate factors be derived from in-depth analysis of the relevant conditions.

LOG VOLUME

OFFICIAL SCALING RULES OF WESTERN CANADA

In 1970, the federal government released its white paper on metric conversion in Canada. The change-over to the use of the metric system for log volume measurement is now essentially complete. Nationally, the official guide to metric log scaling is the CSA National Standard of Canada on "Scaling Roundwood". While provincial scaling rules all employ the Smalian formula for log volume estimates as specified by the above standard, minor variations in application can result in differences in volumes estimated. The formulas for metric scaling rules in western Canada are shown in Table 1. Some differences between these rules and their application are noted below. For a thorough appreciation of these, the reader is referred directly to the respective scaling manuals.

British Columbia

In British Columbia the radius, not the diameter, is used to measure logs, and scale sticks are designed so that the radius is read when measuring across the end diameter.

Table 1

Metric Scaling Rule Formulas

Province[1]	Computational Formulas[2]
British Columbia Metric Scale	$V = \left(r_1^2 + r_2^2 \right) \times L \times 0.0001570796$
Alberta Cubic Metre Scale[3]	$V = \left(D_1^2 + D_2^2 \right) \times L \times 0.00003927$
Alberta Log Rule[4]	$Vbf = 0.034548\ D^2 - 0.273834\ D$ (formula for one 2 m section)
Saskatchewan	$V = \left(D_1^2 + D_2^2 \right) \times L \times 0.00003927$
Manitoba - Method One	$V = \left(D_1^2 + D_2^2 \right) \times L \times 0.00003927$
Manitoba - Method Two	$V = L \times \frac{\pi}{40000} \times \left[D + (L \times 0.5) \right]^2$

[1]All cubic scales use the basic Smalian Formula:

$$V = \frac{A_1 + A_2}{2} \times L$$

[2]Computational formulas were derived from individual scaling manuals.
[3]In the Alberta Cubic Metre Scale, the butt diameter is calculated using a taper factor formula.
[4]This is one of several log scale formulas developed for this rule.

Definitions:

V = gross log volume in cubic metres
Vbf = gross log volume in board feet

$A_1, A_2 = \frac{\pi r^2}{10000}$ or $\pi\left(\frac{D}{2 \times 100}\right)^2$ end surface areas inside bark in square centimetres

r_1, r_2 = end radii in centimetres
D_1, D_2 = end diameters in centimetres
L = length in metres
D = top or small end diameter in centimetres

Alberta

The Alberta Cubic Metre Scale is based on the measurement of the top end diameter and the length of the log. Using these two measurements, log volume can be obtained by reference to the "Alberta Cubic Metre Scale" table. Volumes in this table were calculated using Smalian's formula with a variable taper factor used to determine butt diameters. To derive taper factors, a sample of logs was used to relate top diameter to taper. The following taper factor formula was derived:

$$\text{Taper in inches per eight feet} = 0.79418 - 0.03511\ D + 0.00535\ D^2$$

where D = top diameter in inches. This was converted to metric measure as follows:

$$\text{Taper factor in centimetres per metre} = \frac{\text{taper in inches per 8 feet} \times 2.54}{2.4384}$$

A second official rule was developed in Alberta (the Alberta Log Rule) to allow log volume estimation in board feet, based on metric measurements for diameter and length. A volume table is provided for this purpose. The rule is based on the premise that nominal 2-inch (in) lumber is produced, using a 5/16-in kerf. Total log volumes were derived by accumulating volumes of 1.2 metre (m) sections, assuming log taper to be 1.25 centimetre (cm) every 1.2 m. Using these and other assumptions, a series of log scale formulas were derived to calculate board-foot volumes for logs of different top diameters and lengths.

Saskatchewan

In Saskatchewan, scaling large quantities of individual logs requires measuring the diameter at each end in centimetres and the length in metres.

Manitoba

In Manitoba there are two methods used to obtain the gross volume of solid wood of an individual log in cubic metres (m^3). Method one requires that both end diameters be measured in centimetres and the length in metres. Method two requires measuring the small end diameter and the length to obtain volumes calculated by a formula (shown in Table 1) which assumes a taper of 1 cm per metre of length.

For purposes of comparison, Table 2 shows the volumes for similar sized logs based on the different formulas in Table 1. The precision and rounding of measurements specified in individual scaling rules, different taper factors and formulas, account for the volume variations. Details on these factors and defect measurement and deductions can be found in the scaling manual for each province.

Table 2

Five Metre Log Volumes For Official Rules of Western Canada

Log Top Diameter (cm)	B.C. Metric Scale[1] (m^3)	Alberta Cubic Metre Scale[2] (m^3)	Alberta Log Rule[3] (fbm)	Saskatchewan Cubic Metre Scale[1] (m^3)	Manitoba Cubic Metre Scale[4] Method 1 (m^3)	Manitoba Cubic Metre Scale[4] Method 2 (m^3)
10	.070	.057	7	.057	.057	.060
12	.078	.078	13	.077	.077	.080
14	.117	.102	19	.101	.100	.104
16	.129	.130	26	.127	.126	.131
18	.177	.161	35	.157	.155	.161
20	.192	.196	45	.190	.188	.194
22	.249	.234	56	.226	.223	.230
24	.267	.277	68	.265	.262	.269
26	.334	.324	81	.308	.303	.311
28	.355	.374	96	.353	.348	.357
30	.431	.429	111	.402	.395	.405
32	.455	.488	128	.454	.446	.457
34	.541	.552	146	.509	.500	.511
36	.568	.620	165	.567	.557	.569
38	.664	.692	185	.628	.617	.630
40	.694	.770	206	.693	.681	.693
42	.798	.852	229	.760	.746	.760
44	.832	.939	252	.831	.816	.830
46	.946	1.030	277	.905	.888	.903
48	.983	1.127	303	.982	.963	.980
50	1.107	1.230	330	1.062	1.042	1.059
54	1.280	1.450	388	1.232	1.208	1.226
58	1.465	1.692	450	1.414	1.387	1.406
62	1.663	1.958	517	1.609	1.578	1.599
66	1.873	2.247	588	1.816	1.781	1.803
70	2.096	2.562	664	2.036	1.997	2.020
74	2.332	2.902	745	2.268	2.225	2.249

[1]Assumes taper of 1 cm per metre of length for this comparison.

[2]Variable taper factor predetermined from a sample of logs.

[3]Taper of 1.042 cm per m of length.

[4]In Manitoba, log lengths are measured in 0.2 m classes with boundaries on the even 0.2 m. A 5.0 m log would be in the 4.9 m class.

BOARD-FOOT LOG RULES
BASED ON IMPERIAL MEASUREMENTS

Although no longer officially used, formulas for board-foot log-scaling rules of western Canada are given in Table 3 for reference purposes.

The **B.C. Board-Foot Rule** is no longer in official use, but is still used by industry for log trading on the B.C. Coast.

The **Brereton Log Rule** is sometimes used in the log export trade. This rule does not allow for waste in slabs and kerfs, whereas the other board-foot rules do. It converts cubic volume, calculated using the mean of the two end diameters, to board feet by multiplying by 12.

The **International 5/16-in and 1/4-in Rules** were commonly used in the Prairie provinces until recently, and are still in use in parts of the U.S.A.

The **Scribner Log Rule** is the official rule in many parts of the United States, including the Pacific Northwest. It is a diagram rule with volumes rounded to the nearest 10 board feet.

For comparison, log volumes estimated using several board-foot rules for selected log measurements are given in Table 4 for 16-ft logs and Table 5 for 32-ft logs. These log rules are described in detail in the U.S.D.A. Forest Service report "A Collection of Log Rules" (Freese, 1974).

STACKED WOOD SCALING

Metric Measure

Metric measurement of stacked wood is now officially practiced in Canada. Stacks of logs of equal length may be measured either in cubic metres of solid wood or in stacked cubic metres, based on measurements of length, width and height of the stack to the nearest 0.02 metre. An average measure is taken if the stacking is irregular. The volume of the stack in cubic metres is the product of the three measurements.

An average conversion ratio between a cubic metre and a stacked cubic metre is:

$$1\ m^3 \text{ (solid wood)} = 1.506\ m^3 \text{ (stacked)}$$
$$1\ m^3 \text{ (stacked)} = 0.664\ m^3 \text{ (solid wood)}$$

As indicated in Table 6, the range around this latter figure can be as much as 0.31 m^3 fibre/m^3 (stacked), depending on the type or condition of the logs or bolts in the pile.

Cord Measure

Cord measure was commonly used in the past to estimate the volume of such forest products as shingle bolts, fuelwood and pulpwood.

A cord is defined as a volume of wood four feet (ft) high, four ft wide and eight ft long, thus encompassing 128 cubic feet (ft^3) of space. The volume of solid wood in a cord depends on the size, shape and length of the logs in the

Table 3

Board Foot Log Scale Formulas

Log Rule	Formulas
British Columbia Board Foot Rule	$V = 0.0476\ (d-1.5)^2 \times L$
Brereton	$V = 0.06545\ (D^2L)$
International 5/16 Inch Log Rule[1]	$V = 0.864\ (0.22\ d^2 - 0.71\ d)$ (for 4-foot sections)
International 1/4 Inch Log Rule[2]	$V = 0.905\ (0.22\ d^2 - 0.71\ d)$ (for 4-foot sections)

[1]Formerly used in Alberta.

[2]Formerly used in Saskatchewan and Manitoba.

Definitions:

V = volume in board feet
d = small-end diameter inside bark in inches
L = length in feet
D = mean of end diameters in inches

Table 4

Board Foot Volumes for 16-Foot Logs
with Taper of 1 Inch in 8 Lineal Feet

Log Top Diameter (in)	British Columbia Log Scale[1]	International 5/16" Log Rule	International 1/4" Log Rule[2]	Scribner Log Scale[1, 3]
4	5	6	5	10
5	9	11	10	20
6	15	18	20	20
7	23	27	30	30
8	32	37	40	30
9	43	49	50	40
10	55	62	65	60
11	69	76	80	70
12	84	93	95	80
13	101	110	115	100
14	119	129	135	110
15	139	150	160	140
16	160	172	180	160
17	183	196	205	180
18	207	222	230	210
19	233	248	260	240
20	261	277	290	280
21	290	307	320	300
22	320	338	355	330
23	352	371	390	380
24	386	405	425	400
25	421	441	460	460
26	457	479	500	500
27	495	518	540	550
28	535	558	585	580
29	576	600	630	610
30	619	644	675	660

[1]Taper not considered in log scale up to log lengths of 40 feet.

[2]Rounded to nearest 5 board feet.

[3]Rounded to nearest 10 board feet.

Table 5

Board-Foot Volumes for 32-Foot Logs
with Taper of 1 Inch in 8 Lineal Feet

Log Top Diameter (in)	British Columbia Log Scale[1]	International 5/16" Log Rule	International 1/4" Log Rule[2]	Scribner Log Scale[1, 3]
4	10	24	25	20
5	19	38	40	30
6	31	55	60	50
7	46	76	80	60
8	64	99	105	70
9	86	125	130	90
10	110	155	160	120
11	137	186	195	140
12	168	222	230	160
13	201	260	275	190
14	238	301	315	230
15	278	346	365	280
16	320	394	410	320
17	366	444	465	370
18	415	499	520	430
19	466	555	580	480
20	521	615	645	560
21	579	678	710	610
22	640	743	780	670
23	704	812	850	750
24	771	884	925	810
25	841	959	1000	920
26	914	1037	1085	1000
27	990	1118	1170	1100
28	1070	1202	1260	1160
29	1152	1289	1350	1220
30	1237	1379	1445	1310

[1]Logs scaled as two 16-foot logs, taking the mid-diameter of the log as the top diameter of the butt section.

[2]Rounded to nearest 5 board feet.

[3]Rounded to nearest 10 board feet.

Table 6

Solid Content of Stacked Wood (Bark Included)

Bolt Mid-Diameter		15 cm (6 in)		5 cm (6 in) to 30 cm (12 in)		30 cm (12 in) +	
Bolt Lengths		1.2 m (4 ft)	2.4 m (8 ft)	1.2 m (4 ft)	2.4 m (8 ft)	1.2 m (4 ft)	2.4 m (8 ft)
Softwoods:							
Straight							
Smooth	(m^3 fibre/m^3 space)	0.70	0.69	0.74	0.73	0.78	0.77
	(ft^3/cord)	90	88	95	93	100	98
Slightly rough and knotty	(m^3 fibre/m^3 space)	0.66	0.63	0.71	0.69	0.75	0.73
	(ft^3/cord)	84	80	91	88	96	94
Not Straight							
Slightly crooked and rough	(m^3 fibre/m^3 space)	0.63	0.59	0.69	0.66	0.73	0.71
	(ft^3/cord)	80	76	88	84	93	91
Crooked, rough and knotty	(m^3 fibre/m^3 space)	0.55	0.51	0.62	0.59	0.65	0.63
	(ft^3/cord)	70	65	79	75	83	80
Hardwoods:							
Straight							
Smooth	(m^3 fibre/m^3 space)	0.66	0.64	0.71	0.69	0.77	0.74
	(ft^3/cord)	85	82	91	88	98	95
Slightly rough and knotty	(m^3 fibre/m^3 space)	0.61	0.57	0.66	0.64	0.72	0.70
	(ft^3/cord)	78	73	85	82	92	90
Not Straight							
Slightly crooked and rough	(m^3 fibre/m^3 space)	0.59	0.55	0.64	0.62	0.70	0.67
	(ft^3/cord)	75	70	82	79	89	86
Crooked, rough and knotty	(m^3 fibre/m^3 space)	0.52	0.47	0.59	0.55	0.61	0.59
	(ft^3/cord)	67	60	75	70	78	75

Source: Flann, 1962. Metric values derived from imperial units.

pile and the bark content. An average conversion ratio commonly used is 85 ft^3 per cord but, as indicated in Table 6, the range around this figure can be as much as 40 ft^3, depending on the condition of the logs or bolts in the pile.

Guernsey (1959) indicated the effect of length on the cubic volume of solid wood per cord to be as follows:

Length of logs	Cubic feet per cord
8 ft	88
16 ft	84
24 ft	80
32 ft	76

Conversion factors used by Statistics Canada to convert between cords and cubic metres are:

1 cord (peeled) = 2.69 m^3 or 85 ft^3,
1 cord (unpeeled) = 2.4069 m^3 or 95 ft^3.

MASS SCALING

A third method of estimating wood volumes is weight scaling all truck loads of logs. By manually scaling random samples of loads, ratios may then be calculated from which to estimate the total log volume. In B.C., a volume-to-mass ratio is determined and multiplied by the total mass. In Manitoba and Saskatchewan, the total mass is divided by a mass-to-volume ratio. In Alberta, a ratio of total mass to sample mass is first obtained, and multiplied by the sample volume. Ratios vary with species, site, stand age, log size, season of year, bark coverage and other factors, so averages are periodically adjusted.

Loads of logs transported from forest to mill are commonly of mixed species, each with a different volume-to-mass or mass-to-volume ratio. The assumption is made that the different species volume percentages in the total sample volume will be represented in the total log population. Species composition is therefore determined on a volumetric basis, not on the basis of its mass. An example of how total volumes are estimated for single and mixed species is shown in Table 7.

Table 7

Volume to Mass Ratio Determinations

R_1 = volume to mass ratio, cubic metres per kilogram
R_2 = mass to volume ratio, kilograms per cubic metre
M = multiplier
s = sample scale in cubic metres
w = sample weight in kilograms
W = log population weight in kilograms
V = log population volume in cubic metres

British Columbia	Alberta	Manitoba/Saskatchewan
Single Species		
Example data: $s = 500\ m^3$, $w = 490\ 000$ kg, $W = 100\ 000\ 000$ kg		
$R_1 = s/w = 0.001\ 020\ 4\ m^3/kg$ $V = R_1 W = 102\ 040.816\ m^3$	$M = W/w = 204.081\ 63$ $V = Ms = 102\ 040.816\ m^3$	$R_2 = w/s = 980\ kg/m^3$ $V = W/R_2 = 102\ 040.816\ m^3$
Mixed Species		
Example data: $s_1 = 280\ m^3$, $s_2 = 140\ m^3$, $s_3 = 140\ m^3$ $w = 450\ 000$ kg, $W = 100\ 000\ 000$ kg		
$R_1 = (s_1 + s_2 + s_3)/w = 0.001\ 244\ 4\ m^3/kg$ $r_1 = s_1/w = 0.000\ 622\ 2\ m^3/kg$ $r_2 = s_2/w = 0.000\ 311\ 1\ m^3/kg$ $r_3 = s_3/w = 0.000\ 311\ 1\ m^3/kg$ $R_1 = r_1 + r_2 + r_3 = 0.001\ 244\ 4\ m^3/kg$ $V = R_1 W = 124\ 444.444\ m^3$	$M = W/w = 222.222$ $V = M(s_1 + s_2 + s_3)$ $= 124\ 444.444\ m^3$	$R_2 = w/(s_1 + s_2 + s_3)$ $= 803.571\ 43\ kg/m^3$ $V = W/R_2 = 124\ 444.444\ m^3$

WOOD DENSITY

BASIC DENSITY

The basic density of a substance is defined as mass per unit volume. Table 8 provides average basic densities of oven dry (o.d.) wood in both pounds per cubic foot and kilograms per cubic metre for western Canadian tree species.

SPECIFIC GRAVITY

The specific gravity of a wood species is defined as the ratio of the species density to the density of water at 4°C. Specific gravities shown in Table 9 are as given by Jessome (1977), or as derived from Smith (1970) on the basis of the densities of Table 8 and a water density of 62.4 pounds per cubic foot.

MOISTURE CONTENTS

The moisture content (MC) of wood is normally expressed in either one of two ways:

Oven-dry Basis

The weight of water is expressed as a percentage of the weight of wood present; i.e. a MC of 30 percent means the weight of water present is 30 percent of the weight of wood present.

$$MC = 100(\text{wt. water}/\text{wt. wood}).$$

Original-weight Basis

The weight of water is expressed as a percentage of the total weight present; i.e. a MC of 30 percent means that 30 percent of the total weight present is attributable to water.

$$MC = 100(\text{wt. water}/\text{total wt.}).$$

The former measure is normally used in the lumber industry and the latter measure in the pulp industry. The former is always more than the latter, as shown in Table 10.

Average green moisture contents for some tree species are given in Table 11. Care should be exercised in using these data since the green moisture content of a species is highly variable.

Table 8

Basic Density of Wood

(Volume green, weight oven-dry)

Softwood Species	lb/ft^3	kg/m^3	Hardwood Species	lb/ft^3	kg/m^3
Cedar, eastern white	18.66	299	Alder, red	23.28	373
Cedar, western red[3]	20.53	329	Ash, black	29.20	468
Cypress, yellow	26.15	419	Ash, green	30.33	486
Douglas-fir	28.08	450	Aspen, trembling	23.34	374
Fir, alpine[3]	20.53	329	Aspen, largetooth	24.34	390
Fir, amabilis[3]	23.52	377	Basswood	22.46	360
Fir, balsam[1]	20.90	335	Birch, white	31.57	506
Hemlock, western[3]	26.40	423	Birch, western white	31.70	508
Larch, western[3]	28.08	450	Cottonwood, eastern	21.96	352
Pine, jack	26.27	421	Cottonwood, black[4]	21.10	338
Pine, lodgepole[3]	25.52	409	Elm, white	32.70	524
Pine, red	24.46	392	Ironwood	40.68	652
Pine, western white	22.15	355	Maple, broadleaf	29.08	466
Pine, ponderosa[2, 3]	24.21	388	Maple, Manitoba	25.96	416
Pine, eastern white	22.71	364	Oak, bur	37.38	599
Spruce, black	25.33	406	Poplar, balsam[4]	21.04	337
Spruce, Engelmann[3]	22.15	355			
Spruce, Sitka	21.65	347			
Spruce, white[3]	22.46	360			
Tamarack	30.26	485			

[1]Balsam fir grows in all provinces except B.C. True firs growing in B.C. are commonly referred to as "balsam".

[2]Commonly known as yellow pine in B.C.

Sources:

[3]Smith, 1970.

[4]Kellogg and Swan, 1983.

Remainder of species: Jessome, 1977.

Table 9

Specific Gravity

(Volume green, weight oven-dry)

Softwood species	Specific gravity	Hardwood species	Specific gravity
Cedar, eastern white	0.299	Alder, red	0.373
Cedar, western red[3]	0.329	Ash, black	0.468
Cypress, yellow	0.419	Ash, green	0.486
Douglas-fir	0.450	Aspen, trembling	0.374
Fir, alpine[3]	0.329	Aspen, largetooth	0.390
Fir, amabilis[3]	0.377	Basswood	0.360
Fir, balsam[1]	0.335	Birch, white	0.506
Hemlock, western[3]	0.423	Birch, western white	0.508
Larch, western[3]	0.450	Cottonwood, eastern	0.352
Pine, jack	0.421	Cottonwood, black[4]	0.338
Pine, lodgepole[3]	0.409	Elm, white	0.524
Pine, red	0.392	Ironwood	0.652
Pine, western white	0.355	Maple, broadleaf	0.466
Pine, ponderosa[2, 3]	0.388	Maple, Manitoba	0.416
Pine, eastern white	0.364	Oak, bur	0.599
Spruce, black	0.406	Poplar, balsam[4]	0.337
Spruce, Engelmann[3]	0.355		
Spruce, Sitka	0.347		
Spruce, white[3]	0.360		
Tamarack	0.485		

[1]Balsam fir grows in all provinces except B.C. True firs growing in B.C. are commonly referred to as "balsam".

[2]Commonly known as yellow pine in B.C.

Sources:

[3]Smith, 1970.

[4]Kellogg and Swan, 1983.

Remainder of species: Jessome, 1977.

Table 10

Moisture Content Comparison[1]

Moisture content, oven-dry basis	Moisture content, original-weight basis
10	9
20	17
30	23
40	29
50	33
60	37
70	41
80	44
90	47
100	50
110	52
120	55
130	57
140	58
150	60
160	62
170	63
180	64
190	66
200	67

[1]Relationships between oven-dry (o.d.) and original-weight (o.w.) basis:

$$\text{MC o.d.} = \frac{100 \times \text{MC o.w.}}{100 - \text{MC o.w.}}$$

$$\text{MC o.w.} = \frac{100 \times \text{MC o.d.}}{100 + \text{MC o.d.}}$$

Table 11

Average Green Moisture Contents, (Oven-dry Basis)

Species	Moisture content (%)		
	Heartwood	Sapwood	Mixed
Cedar, eastern white[1]	32	240	93
Cedar, western red	58	249	62[2]
Cypress, yellow	32	166	52[2]
Douglas-fir, coastal[2]	39	151	45
Douglas-fir, interior[2]	31	132	43
Fir, alpine[2]	56	153	65
Fir, amabilis[2]	55	164	69
Fir, balsam[1]	88	173	118
Fir, grand	91	136	-
Hemlock, western[2]	55	143	85
Larch, western[2]	35	119	49
Pine, jack[3]	-	-	51
Pine, lodgepole[2]	38	115	50
Pine, red[1]	32	134	-
Pine, western white	62	148	75[2]
Pine, ponderosa[2]	40	148	76
Spruce, black[2]	52	113	77
Spruce, Engelmann[5]	-	-	64
Spruce, Sitka	41	142	43[2]
Spruce, white[2]	51	163	59
Alder, red[3]	-	-	101
Aspen, trembling[4]	-	-	90
Aspen, largetooth[1]	95	113	-
Basswood[1]	81	133	-
Birch, white[1]	74	72	73
Birch, western white[3]	-	-	72
Cottonwood, eastern[1]	162	146	-
Cottonwood, black[2]	-	-	175
Elm, white[1]	95	92	-
Ironwood[1]	-	-	52
Maple, broadleaf[3]	-	-	71
Poplar, balsam[4]	-	-	135

Sources:

[1]Flann, 1962.
[2]Information on file, Forintek Canada Corp., Western Laboratory.
[3]Forest Products Laboratories of Canada, 1956.
[4]Mackay, 1974.
[5]Smith, 1970.

All other figures from U.S.D.A., For. Serv., Wood Handbook, 1974.

SAPWOOD THICKNESS

Data presented by Lassen and Okkonen (1969), shown in Table 12, indicate that, in general, sapwood thickness increases with tree diameter, but the percentage of sapwood decreases with increasing diameter.

Sapwood normally has a greater moisture content than heartwood, so it is usually the case that the green weight (per unit volume) of small logs is greater than that of large logs of the same species.

GREEN DENSITY

Based on the basic densities in Table 8 and mixed moisture contents in Table 11, average green densities for western Canadian species would be as indicated in Table 13.

Table 12

Sapwood Statistics

Tree DIB at breast height (in)	Douglas-fir, coastal	Douglas-fir, interior	Western larch	Lodgepole pine	Ponderosa pine	Western red cedar	Engelmann spruce
			Average Sapwood Thickness (in)				
5.0- 9.9	1.27	0.99	0.79	1.62	2.76	0.81	1.14
10.0-14.9	1.72	1.30	0.89	2.13	4.11	0.96	1.70
15.0-19.9	1.96	1.48	0.89	2.60	4.94	1.11	1.93
20.0-24.9	2.05	1.67	0.81	3.32	5.12	1.11	1.97
25.0-29.9	2.13	1.78	0.79	3.99	5.21	1.18	2.21
30.0-34.9	2.10	1.98	-	-	5.63	1.09	2.31
35.0-39.9	2.17	1.79	-	-	5.86	1.00	1.71
40.0-44.9	2.17	1.92	-	-	5.66	0.99	-
45.0-49.9	2.13	-	-	-	5.29	1.11	-
			Average Sapwood Area as Percentage of Cross-Sectional Area				
5.0- 9.9	57	46	38	68	93	39	52
10.0-14.9	48	37	27	57	88	28	47
15.0-19.9	40	31	19	51	81	24	39
20.0-24.9	33	28	14	50	70	19	32
25.0-29.9	29	24	11	50	62	16	30
30.0-34.9	24	23	-	-	57	13	26
35.0-39.9	22	18	-	-	53	10	17
40.0-44.9	19	17	-	-	46	9	-
45.0-49.9	17	-	-	-	40	9	-

Source: Thicknesses from Lassen and Okkonen, 1969.

Table 13

Average Green Densities

Species	Green Density	
	lb/ft^3	kg/m^3
Cedar, eastern white	36.0	577
Cedar, western red	33.3	533
Cypress, yellow	39.7	637
Douglas-fir, coastal	40.7	652
Douglas-fir, interior	40.1	643
Fir, alpine	33.9	543
Fir, amabilis	39.7	637
Fir, balsam	45.6	730
Hemlock, western	48.8	782
Larch, western	41.8	670
Pine, jack	39.7	635
Pine, lodgepole	38.3	613
Pine, western white	38.8	621
Pine, ponderosa	42.6	683
Spruce, black	44.8	718
Spruce, Engelmann	36.3	582
Spruce, Sitka	31.0	496
Spruce, white	35.7	572
Alder, red	46.8	750
Aspen, trembling	44.3	710
Birch, white	54.6	875
Birch, western white	54.5	873
Cottonwood, black	58.0	930
Ironwood	61.8	990
Maple, broadleaf	49.7	797
Poplar, balsam	49.4	792

Source: derived from data in Tables 8 and 11.

BARK

BARK THICKNESS

Bark thickness varies with position in the tree, normally decreasing from ground level to tree top. Estimates of bark thickness in standing trees related to section diameter for various species of western Canada can be obtained from the regression equations of Smith and Kozak (1967) shown in Table 14. Average bark thicknesses from the same source are given in Table 15, for fairly small trees of Northwestern species. Average bark proportions, moisture contents and specific gravities at the base of the same trees are shown in Table 16.

BARK VOLUMES

Average bark volumes based on double-bark thickness (DBT) as a percentage of diameter outside bark (DOB) are given in Table 15 for a sample of relatively small trees. However, for bark volume estimates in specific situations, the following method should be used.

Bark volumes for any section can be estimated using the equations of Table 14. For example, the equation given for DBT of coast Douglas-fir is:

$$DBT = -0.234 + 0.139(DOB)$$

Bark volume (BV) as a percentage of total volume (TV) of wood plus bark is:

$$BV\%TV = \left(\frac{DOB^2 - DIB^2}{DOB^2}\right) \times 100$$

where: DIB is diameter inside bark and
DIB = DOB - DBT

Bark volume as a percentage of wood volume (WV) is:

$$BV\%WV = \left(\frac{DOB^2 - DIB^2}{DIB^2}\right) \times 100$$

Thus for a 20-in DOB coastal Douglas-fir:

DBT = -0.234 + 0.139(20) (from Table 14)
= 2.546 in
DIB = 20 - 2.546 in
= 17.454 in

$$BV\%TV = \left(\frac{20^2 - 17.454^2}{17.454^2}\right) \times 100$$

= 31.3 percent

Calculated bark volume percentages should be reduced for bark fissures and voids where applicable. Krier and River (1968) calculated void volumes for three species as follows:

Table 14

Regression of Double-Bark Thickness (DBT) on Diameter Outside Bark (DOB)

Species	Imperial Constant (a)	Metric Constant[1] (a)	Regression Coefficient (b)
Cedar, western red, coastal	0.434	1.102	0.025
Cedar, western red, interior	0.303	0.770	0.041
Cypress, yellow	0.243	0.617	0.030
Douglas-fir, coastal	-0.234	-0.594	0.139
Douglas-fir, interior	-0.403	-1.024	0.170
Fir, amabilis	0.290	0.737	0.029
Fir, alpine	0.051	0.130	0.058
Hemlock, western, coastal	0.305	0.775	0.044
Hemlock, western, interior	0.043	0.109	0.086
Pine, lodgepole	0.073	0.185	0.039
Pine, ponderosa	0.208	0.528	0.103
Pine, western white	0.107	0.272	0.049
Spruce, Sitka	0.394	1.001	0.009
Spruce, white, Englemann	0.149	0.378	0.044
Alder, red	0.156	0.396	0.044
Aspen, trembling	0.103	0.262	0.065
Cottonwood, black	0.064	0.163	0.081
Maple, broadleaf	0.107	0.272	0.039
White birch	0.132	0.335	0.051

Example: For 20-inch DOB coastal Douglas-fir,
DBT = -0.234 + 0.139(20) = 2.546"

For 50-cm DOB coastal Douglas-fir,
DBT = -0.594 + 0.139(50) = 6.36 cm

[1]Derived for metric measurements.

Source: from Smith and Kozak, 1967.

Table 15

Bark Statistics For Western Tree Species

Species	No. of Sections	No. of Trees	DBH (in)			Ave. DBT		Ave. DBT % of DOB	Bark volume, % of	
			Min.	Ave.	Max.	mm	in		Wood Vol.	Total Vol.
Cedar, western red, coastal	924	84	6	20	51	19.0	0.75	7.2	16.1	13.9
Cedar, western red, interior	946	86	5	16	48	18.5	0.73	7.9	17.9	15.2
Cypress, yellow	748	68	6	14	44	13.5	0.53	6.8	15.1	13.1
Douglas-fir, coastal	1067	97	5	22	71	47.2	1.86	11.7	28.2	22.0
Douglas-fir, interior	858	78	5	18	42	39.9	1.57	12.4	30.4	23.3
Fir, amabilis[1]	946	86	6	18	50	16.5	0.65	6.1	13.4	11.8
Fir, alpine[1]	1056	96	5	10	24	11.9	0.47	7.0	15.6	13.5
Hemlock, western, coastal	891	81	5	16	42	20.6	0.81	8.5	19.5	16.3
Hemlock, western, interior	671	61	6	12	28	19.6	0.77	9.4	21.8	17.9
Pine, lodgepole	4994	454	5	11	23	9.7	0.38	5.2	11.2	10.1
Pine, ponderosa	1100	100	6	18	40	38.9	1.53	12.6	30.9	23.6
Pine, western white	1045	95	6	16	27	16.8	0.66	6.3	12.9	12.2
Spruce, Sitka[1]	429	39	6	30	85	14.5	0.57	4.4	9.4	8.6
Spruce, white, Englemann[1]	1331	121	5	13	26	14.2	0.56	6.7	14.9	13.0
Alder, red	946	86	5	11	18	12.7	0.50	7.0	15.6	13.5
Aspen, trembling	1309	119	5	10	21	14.7	0.58	8.6	19.8	16.5
Cottonwood, black	1397	127	5	12	48	17.8	0.70	9.6	22.4	18.3
Maple, broadleaf	396	36	6	13	23	11.9	0.47	5.4	11.7	10.5
White birch	803	73	5	9	21	11.4	0.45	8.2	18.6	15.7

[1]Local names, as in Table 14.

Source: from Smith and Kozak, 1967.

Table 16

Inner and Outer Bark Proportions, Moisture Contents and Densities (Second-Growth Trees)

Species	Bark Proportions		Moisture Content (%)[1]		Specific Gravity[2]	
	Inner	Outer	Inner	Outer	Inner	Outer
Cedar, western red	.36	.64	88	37	.361	.385
Cedar, yellow	.52	.48	145	79	.406	.378
Douglas-fir	.38	.62	133	80	.451	.427
Fir, amabilis	.65	.35	77	40	.525	.581
Fir, grand	.71	.29	81	51	.627	.702
Hemlock, western	.54	.46	134	65	.449	.564
Larch, western	.21	.79	99	44	.431	.348
Pine, lodgepole	.30	.70	128	42	.335	.508
Pine, ponderosa	.12	.88	78	21	.364	.343
Pine, western white	.23	.77	118	75	.310	.535
Spruce, Engelmann	.59	.41	121	60	.448	.528
Spruce, Sitka	.45	.55	112	55	.439	.620
Spruce, white	.58	.42	104	50	.451	.498
Alder, red	.56	.44	88	66	.520	.615
Aspen	.35	.65	121	93	.369	.536
Birch	.65	.35	68	22	.634	.658
Cottonwood, black	.48	.52	130	77	.406	.438
Maple, broadleaf	.68	.32	134	70	.658	.452

[1]Oven-dry basis.

[2]Volume green, weight oven-dry.

Source: Smith and Kozak, 1971.

Ponderosa pine	26 percent	void volume,
Douglas-fir	27 percent	" "
Western larch	28 percent	" "

Using this information, the Douglas-fir bark volume as a percentage of wood volume for the above example would be:

$$BV\%WV = (31.3)(.73) = 22.8 \text{ percent,}$$

or, in general,

$$BV\%WV = \left(\frac{DOB^2 - DIB^2}{DIB^2}\right) \times (100 - V)$$

where V is percentage void volume.

In addition, when calculating volumes of bark available at mill yards, deductions must be made for losses in thickness and coverage in transit from stump to yard. Thus, the general calculaton for bark volume as a percentage of wood volume at mill yards or log ponds would be:

$$BV\%WV = \left(\frac{DOB^2 - DIB^2}{DIB^2}\right) \times (100 - V - Y)$$

where Y is the percentage of bark lost in transit.

BARK COVERAGE

Bark coverage at final log destination is important from the point of view of potential hog fuel availability for power generation.

Results of studies of bark coverage made by this laboratory on the B.C. coast are shown in Table 18. Average coverages appear to bear little relationship to transport distance or method.

BARK DENSITY

Specific gravity of inner and outer bark of small trees of Northwestern species presented by Smith and Kozak (1971) are given in Table 16. Alternative bark density data presented in Table 17 also provide an idea of the variability to be expected in bark densities.

Table 17

Bark Density and Bark Density/Wood Density Ratios

Species	Bark Density[1]				Bark/Wood Ratio[2]
	Average		Range		
	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	
Cedar, western red[3]	21	336	17 - 24	272 - 384	1.02
Cypress, yellow	21	336	-	-	0.80
Douglas-fir[3]	31	497	21 - 36	336 - 577	1.10
Fir, alpine	31	497	-	-	1.51
Fir, amabilis	31	497	26 - 35	416 - 561	1.32
Hemlock, western (coastal)[3]	34	545	24 - 49	384 - 785	1.29
Hemlock, western (interior)	30	481	-	-	1.14
Larch, western	31	497	-	-	1.10
Pine, jack	33	529	25 - 42	400 - 673	1.26
Pine, lodgepole	33	529	-	-	1.29
Pine, western white	32	513	-	-	1.42
Pine, ponderosa	31	497	-	-	1.28
Spruce, black	24	384	19 - 28	304 - 449	0.94
Spruce, white	28	449	22 - 34	352 - 545	1.25

[1]Volume green, weight oven-dry.

[2]Wood densities from Table 8.

[3]Old growth - B.C. coast.

Source: Derived from Dobie, 1965; and Smith and Kozak, 1967.

Table 18

Survey of Bark Coverage at Destination - B.C. Coast Waterborne Logs

Species	Total Logs	Log top diameter (cm)		% Bark coverage		Transportation	
		Ave.	Range	Ave.	Range	Distance (km)	Methods
Western hemlock	102	23	10 - 46	55.6	0-100	48	Flat raft
	103	26	10 - 41	75.0	0-100	161	Flat raft
	99	55	25 - 81	76.0	9-100	161	Flat raft
	97	58	30 - 96	62.9	0-100	64	Bundled
Amabilis fir	101	20	10 - 30	65.3	0-100	48	Flat raft
	102	23	10 - 36	80.0	0-100	161	Flat raft
	81	51	36 - 76	75.0	9-100	161	Flat raft
	62	52	20 -102	65.7	27-100	64	Bundled
Douglas-fir	104	48	36 - 96	65.8	0-100	772	Barged
	107	54	30 -102	62.9	0-100	64	Bundled
	151	29	10 - 56	85.8	0-100	56	Bundled
	92	38	10 -122	50.8	0-100	451	Flat raft
	108	49	25 -117	57.2	0-100	209	Flat raft
Western red cedar	95	81	20 -147	41.3	0-100	48	Flat raft
	216	35	10 - 76	29.6	0-100	121	Flat raft
	100	39	20 - 66	36.8	0-100	772	Barged
Sitka spruce	125	60	25 -122	34.6	0-100	724	Barged

SAWMILLING

LUMBER SIZES

Imperial and metric dimensions of rough and dressed softwood lumber commonly produced in Canada are shown in Table 19. More complete lumber size information is contained in the National Lumber Grades Authority "Standard Grading Rules for Canadian Lumber" and the Canadian Wood Council's "Metric Manual for Wood Products".

LUMBER VOLUMES

In North America, the standard unit of measure of lumber volume is the board foot (1 ft long by 1 ft wide by 1 in thick), and the volume is calculated on nominal sizes. The cubic content of 1,000 board feet (fbm) is 83.33 cubic feet (ft^3) based on nominal dimensions. The cubic content based on actual sizes varies with lumber size as shown in Table 20.

In the metric system, lumber volumes are expressed in cubic metres. Factors used to convert between imperial and metric lumber volumes, based on nominal sizes are as follows:

$$1\ m^3 = 424\ \text{fbm},$$
$$1{,}000\ \text{fbm} = 2.36\ m^3.$$

Normally, when lumber is sold in metric units, the volume in m^3 is based on actual sizes. Hence the conversion factor between fbm and m^3 will vary by lumber size, as shown in Table 21.

LINEAL MEASURE

Lumber volumes may also be expressed in lineal measure. Board foot volumes are converted to lineal measure by the following formula:

$$\text{lineal feet} = \frac{\text{board feet} \times 12}{\text{thickness (in)} \times \text{width (in)}}$$

Lineal volumes per thousand board feet and per cubic metre of lumber, for surfaced and rough lumber are shown in Table 22.

LUMBER PACKAGING

Standard packages of lumber conforming to Canadian and American Lumber Standards (CLS and ALS) contain the number of pieces given in Table 23. The number of pieces in overseas export packages is shown in Table 24.

Table 19

Dimensions of Surfaced Softwood Lumber

Nominal Size (in)	Surfaced-Actual Sizes			
	Imperial		Metric[1]	
	Green (in)	Dry (in)	Dry (mm)	Green (mm)
Thickness				
1	25/32	3/4	19	19.8
1 1/4	1 1/32	1	25	26.2
1 1/2	1 9/32	1 1/4	32	32.3
2	1 9/16	1 1/2	38	39.7
2 1/2	2 1/16	2	51	52.4
3	2 9/16	2 1/2	64	65.1
3 1/2	3 1/16	3	76	77.8
4	3 9/16	3 1/2	89	90.5
4 1/2	4 1/16	4	102	103.2
Width[2]				
5	4 5/8	4 1/2	114	117.5
6	5 5/8	5 1/2	140	142.9
7	6 5/8	6 1/2	165	168.3
8	7 1/2	7 1/4	184	190.5
9	8 1/2	8 1/4	210	215.9
10	9 1/2	9 1/4	235	241.3
11	10 1/2	10 1/4	260	266.7
12	11 1/2	11 1/4	286	292.1
14	13 1/2	13 1/4	337	342.9
16	15 1/2	15 1/4	387	393.7

[1]Metric nomenclature is based on the dry size.
[2]Sizes for narrower widths are the same as for thicknesses.

Source:

Forest Management Institute. 1977.

Canadian Wood Council. 1978.

Table 20

Cubic Volume per Thousand Board Feet for Various Lumber Sizes

Nominal Dimensions (inches)	Cubic Feet per Mfbm Lumber[1]	
	Surfaced Green	Surfaced Dry (19% MC)
1 x 2	50.86	46.87
1 x 3	55.61	52.08
1 x 4	57.98	54.69
1 x 6	61.04	57.29
1 x 8	61.04	56.64
1 x 10	61.85	57.81
1 x 12	62.39	58.59
2 x 2	50.86	46.87
2 x 3	55.61	52.08
2 x 4	57.98	54.69
2 x 6	61.04	57.29
2 x 8	61.04	56.64
2 x 10	61.85	57.81
2 x 12	62.39	58.59
3 x 4	63.40	60.76
3 x 6	66.77	63.69
3 x 8	66.73	62.93
3 x 10	67.62	64.24
3 x 12	68.15	65.04
4 x 4	66.10	63.80
4 x 6	69.58	66.84
4 x 8	69.58	66.08
4 x 10	70.51	67.45
4 x 12	71.13	68.36

[1]Based on actual dimensions shown in Table 19.

Table 21

Cubic Meter Conversion Factors[1] per Mfbm Lumber

Rough Green		Surfaced Dry	
Nominal Dimensions (in)	Conversion Factor[1] (m^3/Mfbm)	Actual Dimensions (in)	Conversion Factor (m^3/Mfbm)
1 x 2	2.333	3/4 x 1 1/2	1.321
1 x 3	2.318	3/4 x 2 1/2	1.484
1 x 4	2.333	3/4 x 3 1/2	1.547
1 x 5	2.324	3/4 x 4 1/2	1.586
1 x 6	2.318	3/4 x 5 1/2	1.623
1 x 7	2.327	3/4 x 6 1/2	1.639
1 x 8	2.322	3/4 x 7 1/4	1.599
1 x 9	2.328	3/4 x 8 1/4	1.623
1 x 10	2.324	3/4 x 9 1/4	1.634
1 x 12	2.326	3/4 x 11 1/4	1.657
2 x 2	2.380	1 1/2 x 1 1/2	1.321
2 x 3	2.364	1 1/2 x 2 1/2	1.484
2 x 4	2.380	1 1/2 x 3 1/2	1.547
2 x 5	2.371	1 1/2 x 4 1/2	1.586
2 x 6	2.364	1 1/2 x 5 1/2	1.623
2 x 7	2.373	1 1/2 x 6 1/2	1.639
2 x 8	2.368	1 1/2 x 7 1/4	1.599
2 x 10	2.371	1 1/2 x 9 1/4	1.634
2 x 12	2.372	1 1/2 x 11 1/4	1.657
3 x 3	2.349	2 1/2 x 2 1/2	1.666
3 x 4	2.364	2 1/2 x 3 1/2	1.737
3 x 5	2.355	2 1/2 x 4 1/2	1.780
3 x 6	2.349	2 1/2 x 5 1/2	1.822
3 x 7	2.358	2 1/2 x 6 1/2	1.840
3 x 8	2.353	2 1/2 x 7 1/4	1.796
3 x 10	2.355	2 1/2 x 9 1/4	1.835
3 x 12	2.357	2 1/2 x 11 1/4	1.861
4 x 4	2.380	3 1/2 x 3 1/2	1.812
4 x 5	2.371	3 1/2 x 4 1/2	1.857
4 x 6	2.364	3 1/2 x 5 1/2	1.900
4 x 7	2.373	3 1/2 x 6 1/2	1.920
4 x 8	2.368	3 1/2 x 8 1/4	1.873
4 x 10	2.371	3 1/2 x 9 1/4	1.914
4 x 12	2.372	3 1/2 x 11 1/4	1.941

[1]Variation in conversion factors in rough lumber is caused by rounding metric sizes to the closest millimetre. If not rounded, the factor would be 2.36 for all sizes.

Source: Canadian Wood Council, 1978.

Table 22

Lineal Measure per M Board Feet and per Cubic Meter for Surfaced and Rough Softwood Lumber

Nominal Dimensions (inches)	Lineal Feet per Mfbm lumber	Surfaced		Rough	
		Metric Size (mm)	Lineal Meters per Cubic Meter	Metric Size (mm)	Lineal Meters per Cubic Meter
1 x 2	6000	19 x 38	1385.04	25 x 51	784.31
1 x 3	4000	19 x 64	822.37	25 x 76	526.32
1 x 4	3000	19 x 89	591.37	25 x 102	392.16
1 x 5	2400	19 x 114	461.68	25 x 127	314.96
1 x 6	2000	19 x 140	375.94	25 x 152	263.16
1 x 7	1714	19 x 165	318.98	25 x 178	224.72
1 x 8	1500	19 x 184	286.04	25 x 203	197.04
1 x 9	1333	19 x 210	250.63	25 x 229	174.67
1 x 10	1200	19 x 235	223.96	25 x 254	157.48
1 x 12	1000	19 x 286	184.03	25 x 305	131.15
2 x 2	3000	38 x 38	692.52	51 x 51	384.47
2 x 3	2000	38 x 64	411.18	51 x 76	258.00
2 x 4	1500	38 x 89	295.68	51 x 102	192.23
2 x 5	1200	38 x 114	230.84	51 x 127	154.39
2 x 6	1000	38 x 140	187.97	51 x 152	129.00
2 x 7	857	38 x 165	159.49	51 x 178	110.16
2 x 8	750	38 x 184	143.02	51 x 203	96.59
2 x 10	600	38 x 235	111.98	51 x 254	77.20
2 x 12	500	38 x 286	92.01	51 x 305	64.29
3 x 3	1333	64 x 64	244.14	76 x 76	173.13
3 x 4	1000	64 x 89	175.56	76 x 102	129.00
3 x 5	800	64 x 114	137.06	76 x 127	103.61
3 x 6	667	64 x 140	111.61	76 x 152	86.56
3 x 7	571	64 x 165	94.70	76 x 178	73.92
3 x 8	500	64 x 184	84.92	76 x 203	64.82
3 x 10	400	64 x 235	66.49	76 x 254	51.80
3 x 12	333	64 x 286	54.63	76 x 305	43.14
4 x 4	750	89 x 89	126.25	102 x 102	96.12
4 x 5	600	89 x 114	98.56	102 x 127	77.20
4 x 6	500	89 x 140	80.26	102 x 152	64.50
4 x 7	429	89 x 165	68.10	102 x 178	55.08
4 x 8	375	89 x 184	61.06	102 x 203	48.30
4 x 10	300	89 x 235	47.81	102 x 254	38.60
4 x 12	250	89 x 286	39.29	102 x 305	32.14

Table 23

B.C. Lumber Export Packaging Schedule for Surfaced Four Sides (S4S) Green CLS, ALS

Nominal Thickness		No. of Pieces High	No. of Pieces per Package					
			Nominal Width in Inches (mm)					
(in)	(mm)		3(64)	4(89)	6(140)	8(184)	10(235)	12(286)
1	19	32	576	416	256	192	160	128
2	38	16	288	208	128	96	80	64
3	64	9	162	117	72	54	45	36
4	89	7	-	91	56	42	35	28
6	140	4	-	-	32	24	-	-

Source: Council of Forest Industries of B.C., 1974

Table 24

B.C. Lumber Export Packaging Schedule for Rough and/or Surfaced-to-Size Lumber

Lumber Thickness (in)	No. of Pieces High	Pieces per package — Lumber Width (Inches) 3	4	5	6	7	8	9	10	11	12
		8 - 24 foot lengths[1]									
5/8	36	-	432	-	288	-	216	-	144	-	-
3/4	30	-	360	-	240	-	180	-	120	-	-
7/8	26	-	312	-	208	-	156	-	104	-	-
1	24	360	288	216	192	144	144	120	96	96	96
1 1/4	20	300	240	180	160	120	120	100	80	80	80
1 3/8	17	255	204	153	136	102	102	85	68	68	68
1 1/2	16	240	192	144	128	96	96	80	64	64	64
1 9/16	15	-	180	135	-	-	90	75	60	-	-
1 5/8	15	-	180	135	-	-	90	75	60	-	-
1 3/4	14	210	168	126	112	84	84	70	56	56	56
1 7/8	13	195	156	117	104	78	78	65	52	52	52
2	12	180	144	108	96	72	72	60	48	48	48
2 1/2	9	135	108	81	72	54	54	45	36	36	36
3	8	120	96	72	64	48	48	40	32	32	32
4	6	-	72	54	48	36	36	30	24	24	24
5	4	-	-	36	32	24	24	20	16	16	16
6	4	-	-	-	32	24	24	20	16	16	16
8	3	-	-	-	-	-	18	15	12	12	12
		25 to 40 foot lengths[2]									
1 1/2	16	128	96	64	64	48	48	32	32	32	32
1 3/4	14	112	84	56	56	42	42	28	28	28	28
1 7/8	13	104	78	52	52	39	39	26	26	26	26
2	12	96	72	48	36	36	36	24	24	24	24
2 1/2	9	72	54	36	36	27	27	18	18	18	18
3	8	64	48	32	32	24	24	16	16	16	16
4	6	-	36	24	24	18	18	12	12	12	12
5	4	-	-	16	16	12	12	8	8	8	8
6	4	-	-	-	16	12	12	8	8	8	8
8	3	-	-	-	-	-	9	6	6	6	6

[1]Appropriate package size for lengths up to 24 ft. = 24 in. x 48 in.
[2]Appropriate package size for lengths over 24 ft. = 24 in. x 24 in.

Source: Council of Forest Industries of B.C., 1974.

LUMBER SHRINKAGE

Lumber shrinkage has two components, tangential (i.e., parallel to the annual rings) and radial (i.e., from pith to bark), and varies among species as shown in Table 25. Volumetric shrinkage, shown from green to air dry, is based on an air dry MC of 12 percent. Since shrinkage is essentially linear from 30 to 0 percent MC, an approximation of volumetric shrinkage to any other MC can be obtained by assuming that (30-X)/30 parts of the shrinkage has occurred, where X is the MC for which the estimate is desired. Thus, an estimate of volumetric shrinkage from green to 15 percent MC for western red cedar would be (30-15)/30 x 7.8 percent or 3.9 percent of the green volume.

LUMBER WEIGHTS

The weight of lumber per thousand board feet (Mfbm) can be estimated using data provided in this report. Two methods are recommended below for estimating lumber weights, depending on whether the green or dry lumber volume is known.

Estimating Green Lumber Weight

For green lumber the following formula applies:

$$(\text{Basic Density}) \times (\text{Green Volume}) \times \frac{(100 + \text{MC})}{100}$$

For the basic density of the species refer to Table 8.

For the green volume (ft^3/Mfbm) refer to Table 20.

Example:

Assume 1 Mfbm of white spruce 2 x 4 was surfaced green at a moisture content of 40 percent.

The weight of this 1 Mfbm is estimated to be:

22.46 x 57.98 x 1.40 = 1,823 pounds (lb).

Estimating Dry Lumber Weight

For dry lumber the formula for estimating weight is as follows:

$$\frac{\text{Basic Density}}{(1 - \text{Volumetric Shrinkage})} \times (\text{Dry Volume}) \times \frac{(100 + \text{MC})}{100}$$

For volumetric shrinkage of the species refer to Table 25.

Table 25

Lumber Shrinkage

Species	Percent Shrinkage From Green			
	To Oven-Dry			To Air-Dry[1]
	Radial	Tangential	Volumetric	Volumetric
Cedar, eastern white	1.7	3.6	6.4	3.8
Cedar, western red	2.1	4.5	7.8	4.8
Cypress, yellow	3.7	6.0	9.4	5.0
Douglas-fir	4.8	7.4	11.9	7.0
Fir, alpine	2.6	7.4	9.4	5.6
Fir, amabilis	4.2	8.9	12.5	7.5
Fir, balsam	2.7	7.5	10.7	5.7
Hemlock, western	5.4	8.5	13.0	8.1
Larch, western	5.1	8.9	14.0	8.0
Pine, jack	4.0	5.9	9.6	5.7
Pine, lodgepole	4.7	6.8	11.4	6.6
Pine, red	3.7	6.3	9.6	6.5
Pine, western white	3.7	6.8	10.7	6.0
Pine, ponderosa	4.6	5.9	10.5	6.1
Pine, eastern white	2.5	6.3	8.2	4.5
Spruce, black	3.8	7.5	11.1	6.5
Spruce, Engelmann	4.2	8.2	11.6	6.8
Spruce, Sitka	4.6	7.8	11.7	6.0
Spruce, white	3.2	6.9	11.3	6.8
Tamarack	2.8	6.2	11.2	7.1
Alder, red	4.2	7.0	11.7	8.0
Ash, black	4.3	8.2	13.8	7.9
Ash, green	3.8	5.4	11.4	8.3
Aspen, trembling	3.6	6.6	11.8	8.3
Aspen, largetooth	3.2	6.8	11.7	8.8
Basswood	6.7	9.3	18.4	13.4
Birch, white	5.2	7.2	13.8	10.5
Birch, western white	6.8	9.3	16.0	10.0
Cottonwood, eastern	3.1	7.8	11.8	9.8
Cottonwood, black	3.6	8.8	11.7	8.4
Elm, white	4.4	7.8	15.2	9.4
Ironwood	4.8	8.0	18.2	12.4
Maple, broadleaf	4.1	7.6	12.1	8.2
Maple, Manitoba	3.9	7.4	14.8	9.4
Oak, bur	4.2	5.4	13.7	10.2
Poplar, balsam	3.9	6.4	11.6	9.5

[1]12 percent moisture content

Sources: Kennedy, 1965
U.S.D.A. Wood Handbook, 1955 (Apline fir only).

Example:

Assume 1 Mfbm of white spruce 2 x 4 was surfaced dry at 17 percent MC.

Percent volumetric shrinkage from green to 17 percent MC

$$= \frac{30 - 17}{30} \times 11.3 = 4.90 \text{ percent}$$

The weight of 1 Mfbm is estimated to be

$$= \frac{22.46}{(1 - .049)} \times 54.69 \times 1.17 = 1{,}511 \text{ lb.}$$

Based on an average MC of 15 percent, and appropriate volumetric shrinkages, estimated lumber weights per thousand board feet for various dimensions of dry lumber are shown in Table 26.

Based on an average MC of 15 percent, and appropriate volumetric shrinkages, lumber weights per cubic metre for various species are shown in Table 27.

LUMBER YIELDS

Lumber yields (lumber output/log input) are commonly expressed as either a lumber recovery factor (LRF) or percent yield.

Metric LRF

Where metric log scaling is practiced, lumber yields are expressed in terms of nominal board feet of lumber recovered per scaled cubic metre of log input:

$$\frac{\text{nominal board feet of lumber}}{\text{cubic metres of logs}}$$

The metric LRF can be used to estimate the proportion of the log actually recovered as lumber by converting the numerator of the above term to the actual cubic metre volume equivalent. The percent yield can be derived using the following equation:

$$\text{percent yield} = \frac{\text{LFR}}{1000} \times Y \times 100$$

where Y is the actual cubic metre volume per Mfbm of lumber (Table 21).

This reduces to:

$$\text{percent yield} = 0.1 \text{ (LRF) (Y)}.$$

Table 26

Surfaced Dry Lumber Weights Per M Board Feet

Species	Weight in pounds[1]				
	2 x 4 inches	2 x 6 inches	2 x 8 inches	2 x 10 inches	2 x 12 inches
Cedar, eastern white	1212	1270	1256	1282	1299
Cedar, western red	1344	1407	1392	1420	1439
Cypress, yellow	1726	1808	1787	1824	1849
Douglas-fir	1878	1967	1945	1985	2012
Fir, alpine	1355	1419	1403	1432	1452
Fir, amabilis	1578	1653	1634	1668	1690
Fir, balsam	1389	1455	1438	1468	1488
Hemlock, western	1776	1860	1839	1877	1902
Larch, western	1899	1989	1967	2007	2034
Pine, jack	1736	1818	1797	1835	1859
Pine, lodgepole	1702	1783	1763	1799	1823
Pine, red	1616	1693	1674	1708	1731
Pine, western white	1472	1542	1524	1556	1577
Pine, ponderosa	1607	1683	1664	1699	1702
Pine, eastern white	1489	1560	1542	1574	1596
Spruce, black	1687	1767	1747	1783	1807
Spruce, Engelmann	1479	1549	1532	1563	1584
Spruce, Sitka	1446	1515	1498	1529	1549
Spruce, white	1497	1568	1551	1583	1604
Tamarack	2016	2112	2088	2131	2160
Aspen, trembling	1560	1634	1616	1649	1671
Aspen, largetooth	1626	1703	1684	1719	1742
Balsam, poplar	1405	1472	1455	1485	1505

[1]Based on lumber at 15 percent MC.

Table 27

Metric Weights of Surfaced Dry Lumber[1]

Softwood species	kg/m^3	Hardwood species	kg/m^3
Cedar, eastern white	355	Alder, red	456
Cedar, western red	394	Ash, black	579
Cypress, yellow	506	Ash, green	593
Douglas-fir	550	Aspen, trembling	458
Fir, alpine	397	Aspen, largetooth	476
Fir, amabilis	462	Basswood	456
Fir, balsam	407	Birch, white	625
Hemlock, western	521	Birch, western white	635
Larch, western	556	Cottonwood, eastern	430
Pine, jack	509	Cottonwood, black	413
Pine, lodgepole	499	Elm, white	652
Pine, red	474	Ironwood	825
Pine, western white	431	Maple, broadleaf	570
Pine, ponderosa	471	Maple, Manitoba	517
Pine, eastern white	436	Oak, bur	740
Spruce, black	494	Poplar, balsam	411
Spruce, Engelmann	433		
Spruce, Sitka	424		
Spruce, white	439		
Tamarack	591		

[1]Based on lumber at 15 percent MC.

Example:

For a mill producing dressed, dried 2 x 4s, which has an LRF of 230 fbm/m^3, the percentage of log cubic input recovered as lumber is:

$$0.1 \times 230 \times 1.547 = 35.6 \text{ percent.}$$

Imperial LRF

The LRF expressed in nominal board feet per cubic foot of log volume (fbm/ft^3) is still in use. The LRF expressed in these units can be employed to estimate the proportion of log cubic input recovered as lumber using the following equation:

$$\text{percent yield} = \left(\frac{LRF}{12} \times \frac{Y}{Z} \right) \times 100$$

where Y is the actual cubic feet per Mfbm of lumber (Table 20), and
Z is nominal cubic feet per Mfbm of lumber (83.33).

This reduces to:

$$\text{percent yield} = 0.1 \, (LRF)(Y)$$

Example:

For a mill producing dressed, dried 2 x 4s which has a LRF of 6.5, the percentage of cubic input recovered as lumber is

$$0.1 \, (6.5) \, (54.69) = 35.6 \text{ percent.}$$

Lumber yields vary with sawmill type, log sizes, log quality, products cut, and other factors. Results of studies of lumber yields conducted at various coastal sawmills in B.C. are shown in Table 28. Results of yield studies in B.C. interior mills are shown in Tables 29 and 30.

RESIDUE YIELDS

Sawdust

Sawdust volumes produced in lumber manufacture are a function of kerf thicknesses and the number of saw lines, and thus can be quite variable between mills. The estimates of sawdust yields provided in Table 31 are for mills cutting mainly 2-in thick lumber of random width.

Pulp Chips

Pulp chips are obtained from the slabs, trims, and edgings produced in sawmills, and thus will vary with the volume of lumber recovered and manufacturing practices. The estimates provided in Table 31 are based on the assumption of complete recovery of slabs, trims, and edgings as pulp chips.

Table 28

Surfaced Green Lumber Yields for B.C. Coastal Sawmills Cutting Dimension Lumber

Headrig Type	Species	No. Logs	Avg. Diameter		Avg. Length		Rough Green Yield		Percent of Log Firmwood Scale			Estimated[1] Percent Lumber Yield-Surfaced Green
			(cm)	(in)	(m)	(ft)	(fbm/m^3)	(fbm/ft^3)	Lumber	Sawdust	Chips	
Band	W. Hemlock	303	51	20	10.7	35	254	7.2	57	11	32	44
"	"	121	36	14	5.8	19	215	6.1	47	12	41	37
"	"	282	46	18	6.0	19	268	7.6	51	11	38	46
"	"	90	45	17	9.5	31	222	6.3	53	10	37	38
"	"	157	32	12	8.5	27	215	6.1	52	12	36	37
"	Doug.-fir	374	49	19	5.8	19	254	7.2	57	12	31	44
"	W.R. Cedar	141	51	20	9.8	32	215	6.1	54	13	33	37
Circular	W. Hemlock	140	42	16	5.2	17	222	6.3	47	16	37	38
"	"	81	44	17	5.1	16	173	4.9	42	13	45	30
"	Doug.-fir	393	45	17	8.2	26	272	7.7	61	12	27	47
"	W.R. Cedar	243	38	15	5.2	17	222	6.3	45	9	46	38
"	Y. Cypress	70	57	22	5.1	16	162	4.6	40	12	48	28
Gang	Amabilis fir	190	31	12	5.8	19	251	7.1	54	12	34	43

[1]Based on actual rough sawn and dressed sizes at each mill.

Sources: Dobie, 1975
Dobie, Kasper and Wright, 1975

Table 29

Surfaced Dry Lumber Yields for B.C. Interior Sawmills
Cutting Dimension Lumber From Small Logs

Headrig Type	Log Top Diam. Class[1] (cm)	(in)	Percent of Log Firmwood Scale		LRF	
			Lumber	Chips	(fbm/m^3)	(fbm/ft^3)
Chipping	10	4	28	53	180	5.1
	15	6	31	50	198	5.6
	20	8	33	48	208	5.9
	25	10	36	44	226	6.4
Scrags	10	4	24	48	155	4.4
	15	6	28	44	184	5.2
	20	8	34	38	212	6.0
	25	10	36	36	230	6.5

[1]Diameters indicated are smallest of class.

Source: Dobie, 1978.

Table 30

Surface Dry Lumber Yields for B.C. Interior Sawmills by Log Top Diameter[1]

Log Top Diameter (cm)	No. of Logs	LRF (fbm/m^3)		% Yield	
		Avg.	Range	Avg.	Range
10.0-14.9[3]	366	174	156-193	27.1	24.1-30.0
15.0-19.9[3]	416	197	182-227	31.3	28.8-36.3
20.0-24.9[3]	360	214	192-250	34.2	30.7-40.1
25.0-29.9[3]	332	228	212-251	36.7	33.9-40.8
30.0-34.9[3]	279	236	218-272	38.1	35.5-43.9
35.0-39.9[4]	255	239	212-267	38.9	34.4-43.3
40.0-44.9[4]	181	242	224-267	39.4	36.6-43.5
45.0-49.9[4]	97	232	210-260	37.6	33.7-41.8
50.0-54.9[4]	40	230	207-267	37.2	33.5-43.0

Source: Middleton and Munro, 1985.

[1]Yields are based on sound straight logs as processed in seven sawmills. Primary breakdown equipment included chipper headrigs, circular and band headrigs.

Table 31

Estimated Residue Yields by Sawmill Type in British Columbia

Mill Type	Sawdust	Pulp Chips	Planer Shavings
	(percent of log volume)		
Band Headrig	12	36	11
Circular Headrig	15	38	11
Scrag Mill	15	39	11
Chipping Headrig	6	47	10
Log Gang	11	36	10

Hog-Fuel Volumes by Mill Type and Species[1]

Mill Type	Coastal Douglas-fir	Coastal Western Hemlock	White Spruce
	(percent of log volume)		
Band Headrig	38	35	33
Circular Headrig	41	38	36
Scrag Mill	41	38	36
Chipping Headrig	31	28	26
Log Gang	36	33	31

[1]Based on sawdust and planer shaving volumes above; average bark volumes of Table 15; 25 percent bark losses in transit; 27 percent bark voids for Douglas-fir; 20 percent bark voids for western hemlock; 10 percent bark voids for white spruce.

Planer Shavings

The volume of planer shavings recovered depends on the volume of lumber produced and the dimensions of the rough product compared with the dressed product. The estimates shown in Table 31 are based on lumber thicknesses measured at the mill types indicated.

Hog Fuel

Hog fuel is normally composed of bark, sawdust, and shavings. Thus, the volume of hog fuel produced per Ccf of logs depends on the sawmill, product, species, proportion of bark on logs when processed, and whether or not there is an alternate market for any of these components of hog fuel.

Estimates of hog fuel available from different species and mill types are shown in Table 31. These estimates are based on the assumptions indicated in the table. Because there is little information available on bark loss when harvesting and transporting logs to mill sites, care should be taken in applying these hog-fuel estimates to specific operations. If a high degree of confidence in hog-fuel estimates is required, a series of measurements of the hog-fuel components should be made.

CHIPS AND RESIDUES - UNITS OF MEASURE

The most commonly used measures of chip volumes in western Canada are the "volumetric" (or "gravity-packed") unit (B.C. coast) and the bone-dry unit (B.C. Interior). Bone-dry tons and metric tonnes are used to a limited degree.

Volumetric Unit

This unit is synonymous with the gravity-packed unit (GPU). By definition, the volumetric unit or GPU of chips used on the B.C. coast occupies 200 ft^3 (5.663 m^3) of space.

For chips, the actual solid wood content or solid wood equivalent (SWE) in a GPU is commonly taken as 72 ft^3.

The actual solid wood equivalent in the volumetric unit varies, depending on the type of residue and the degree of compaction. The compaction, in turn, depends mainly on the loading method (chip orientation, impact, layering), chip or particle size distribution, wood species, and moisture content.

Some approximate conversion ratios used to convert a GPU to solid wood equivalent are shown in Table 32. Also shown are the approximate bulk densities of wood residues and chips. The bulk density of planer shavings is highly variable, and relatively low, compared to other residue forms. By passing shavings through a fractionator, bulk densities can be increased significantly.

When chips are loaded onto rail cars they are usually more highly compacted than if they are loaded by gravity from a hopper into trucks. Well designed pneumatic systems can compact up to 25 percent more material into a given space than gravity loading (Oswald, 1979). Nylinder (1972) indicated that pulp chips

Table 32

Wood Residues: Bulk Densities and Solid Wood Equivalents per Volumetric Unit[1]

Residue Type	Bulk Density		Solid Wood Equivalent	
	lb/ft^3	kg/m^3	ft^3/GPU	m^3/GPU
Pulp chips	16-20	256-320	72-80	2.04-2.27
Sawdust	18-22	288-352	80	2.27
Bark	19-28	304-449	81	2.29
Hog fuel	18-24	288-384	71-84	2.01-2.38
Planer shavings[2]				
A. As produced:				
green	4	64	16-18	0.45-0.51
dry-loose	5-6	80-96	32-41	0.91-1.16
dry-compacted	8-9	128-144	52-66	1.47-1.87
B. Fractionated:				
green	6-8	96-128	27-32	0.76-0.91
dry	10-12	160-192	65-83	1.84-2.35

Source: Bulk Densities provided by Rader Canada Ltd.

[1]One volumetric unit (GPU) occupies 200 ft^3 of space.
[2]Solid wood equivalents for planer shavings estimated from bulk densities based on the following assumptions:
a) basic wood density range of 22 to 28 lb/ft^3, representing spruce and Douglas-fir respectively;
b) green wood moisture content range of 80-100 percent MC (o.d. basis);
c) dry wood moisture content of 10 percent (o.d. basis).

from chipper headrigs have about four percent less SWE per unit than chips from conventional mills. The weight of wood in a volumetric unit is determined by the SWE and the species density.

Bone-Dry Unit

By definition, a bone-dry unit (BDU) of pulp chips weighs 2400 pounds when oven dry. The volume of wood SWE in a BDU of chips varies with species density. For white spruce there are 2400/22.46 = 107 ft^3 per unit and for lodgepole pine there are 2400/25.52 = 94 ft^3.

The space occupied by one BDU of chips in a truck, gravity filled from a hopper, is about 300 ft^3 for spruce, 260 ft^3 for lodgepole pine, and 240 ft^3 for Douglas-fir. Also, chips settle on average around five percent in transport by road or rail.

Conversion Between Chip Units

To convert cubic feet of chips to bone-dry units, the arithmetic is:

$$\text{Bone-Dry Units} = \frac{\text{cubic feet chips SWE x basic density (lb/ft}^3\text{)}}{2{,}400}$$

The conversion between the volumetric unit and any weight-based unit depends on the actual solid wood content in the volumetric unit, a ratio which varies as previously explained. The following formula applies when converting to bone-dry units:

$$1 \text{ Volumetric Unit} = \frac{\text{basic density x SWE (ft}^3\text{/vol. unit)}}{2{,}400} = \text{BDUs}$$

Example:

If a volumetric unit of white spruce chips contains 80 ft^3 SWE (Table 32),

$$1 \text{ Volumetric Unit} = \frac{22.46 \times 80}{2{,}400} = 0.75 \text{ BDUs}$$

Similarly, when converting from volumetric units to oven-dry tons, the following formula applies:

$$1 \text{ Volumetric Unit} = \frac{\text{basic density x SWE (ft}^3\text{/vol. unit)}}{2{,}000} = \text{o.d. tons}$$

VENEER AND PLYWOOD

PRODUCT YIELDS IN VENEER MANUFACTURE

Estimates of dried veneer yield can be obtained using the following equation (Dobie and Hancock, 1972):

$$Y = 13.624 + .787X$$

where Y is the dry veneer yield in square feet, and

$$X = \frac{2(D_1^2 - d^2)}{(D_1^2 + D_2)^2} \times \frac{12V}{T}$$

D_1 is block top diameter in inches
D_2 is block butt diameter in inches
d is core diameter in inches
V is block volume in cubic feet (scaled to eight ft lengths)
T is veneer thickness in inches

Using the above formula estimates of 1/8 in veneer yield from various block sizes would be as shown in Table 33.

Veneer and residue yields expressed as a percentage of block volume, based on studies in B.C. and the U.S. Pacific Northwest, are shown in Table 34.

PRODUCT YIELDS IN PLYWOOD MANUFACTURE

Losses between the veneer drier and plywood panel have been estimated to average 16.3 percent (Hunt and Woodfin, 1970). Based on this level of losses and veneer yields in Table 34, plywood recovery and wood input requirements would be as shown in Table 35. Proportions of plywood, lumber, chips, and hogged fuel are shown in Table 36.

PLYWOOD DIMENSIONS, CONVERSION RATIOS AND SURFACE COVERAGE

Canadian softwood plywood panels are produced in standard imperial sizes of 4 x 8 ft (1220 x 2440 mm). Slightly smaller standard metric sizes of 1200 x 2400 mm have also been adopted.

Standard thicknesses for plywood are given in Table 37, with conversion ratios to 3/8-in basis, cubic content per unit of surface measure, and square metre coverage per cubic metre.

Table 33

Dried Veneer Yield Related to Block Size[1]

Block Top Diameter (in)	Block Top Diameter (cm)[2]	Veneer Yield (ft^2-1/8-in.)	Veneer Yield (m^2-3.2 mm)[2]
8	20	142	13.2
10	25	262	24.3
12	30	407	37.8
14	36	576	53.5
16	41	775	72.0
18	46	997	92.6
20	51	1247	115.8
22	56	1527	141.9
24	61	1830	170.0
26	66	2159	200.6
28	71	2515	233.7
30	76	2898	269.2
32	81	3306	307.1
34	86	3738	347.3
36	91	4200	390.2
38	97	4692	435.9
40	102	5203	483.4

[1]Core diameter d = 5 inches (12.7 cm)
Log taper = 1 inch in 8 lineal feet (1.042 cm/metre of length)

[2]Soft conversion to metric units.

Table 34

Product Yields in Veneer Manufacture

Block Breakdown	Interior[1] White Spruce	Interior[1] Douglas-fir	Western[2] Hemlock	Old-Growth[3] Coast Douglas-fir	Second[4] Growth Douglas-fir
			(percent)		
Dried veneer	59	59	44.4	52.7	50.2
Below-grade veneer			3.8	5.6	4.2
Core	14	12	17.5	9.5	14.8
Round-up	18[5]	20[5]	7.7		
Trim	5	5		32.2[6]	30.8[6]
Shrinkage	4	4	6.6		
Clipper green end			20.0		

Source: [1]Dobie and Hancock, 1972
[2]Fahey and Woodfin, 1982
[3]Lane et al., 1973
[4]Fahey, 1974

[5]Includes round-up and green end clipper residue.
[6]Includes round-up, trim and shrinkage.

Table 35

Plywood Yields and Log Requirements Related to Block Diameter[1]

Block Top Diameter (in)	Block Top Diameter (cm)	Plywood Yield (ft^2-3/8 in)	Plywood Yield (m^2-9.5 mm)	Percent of Block Cubic Volume
8	20	39	3.6	38
10	25	73	6.8	47
12	30	114	10.6	52
14	36	160	14.9	55
16	41	216	20.1	57
18	46	278	25.8	58
20	51	345	32.1	59
22	56	421	39.1	60
24	61	511	47.5	61
26	66	603	56.0	61
28	71	697	64.8	61
30	76	808	75.1	62

Block Top Diameter (in)	Block Top Diameter (mm)	ft^2 3/8-in plywood per ft^3 of block	m^2 9.5 mm plywood per m^3 of block	m^3 of blocks per M ft^2 (3/8 inch)	m^3 of blocks per 100 m^2 (9.5 mm)
8	20	12.38	40.6	81	2.469
10	25	15.05	49.4	66	2.012
12	30	16.64	54.6	60	1.829
14	36	17.49	57.4	57	1.737
16	41	18.15	59.5	55	1.676
18	46	18.66	61.2	53	1.615
20	51	18.85	61.8	53	1.615
22	56	19.05	62.5	52	1.585
24	61	19.49	63.9	51	1.554
26	66	19.66	64.5	50	1.524
28	71	19.66	64.5	50	1.524
30	76	19.90	65.3	50	1.524

[1]8 ft (2.44 m) blocks, and 5 in or 12.7 cm core.

Table 36

Product Yields in Plywood Manufacture

Item	Percent of Block Volume[1]
Plywood[2]	49
Lumber[3]	9
Chips	26
Hogged Fuel[4]	21

[1]Total greater than 100 percent because log volume calculated under bark.

[2]Allows 16 percent veneer loss between drier and finished panel (Hunt and Woodfin Jr., 1970).

[3]Assumes a 12.7 cm core for lumber manufacture.

[4]Assumes a 60 percent bark recovery factor and that dry-end residues go to hogged fuel.

Table 37

Standard Thicknesses, Conversion Ratios, and Surface Measure for Plywood

Thickness[1]		Ratio to Convert to 3/8 inch-basis[3]	Cubic Feet per M ft^2	Cubic Metres per 100 m^2	Coverage m^2/m^3
Imperial (in)	Metric (mm)				
Unsanded (sheathing and select) Grades					
5/16	7.5	5/6	26.042	0.75	133.33
3/8	9.5	1	31.250	0.95	105.26
1/2	12.5	1-1/3	41.667	1.25	80.00
5/8	15.5	1-2/3	52.083	1.55	64.52
3/4	18.5	2	62.500	1.85	54.05
	20.5[2]			2.05	48.78
Sanded Grades					
1/4	6	2/3	20.833	0.6	166.67
3/8	8	1	31.250	0.8	125.00
1/2	11	1-1/3	41.667	1.1	90.91
5/8	14	1-2/3	52.083	1.4	71.43
11/16	17	1-5/6	57.290	1.7	58.82
3/4	19	2	62.500	1.9	52.63

[1]From Metric Manual for Wood Products, Canadian Wood Council.
[2]20.5 mm is used to develop 19 mm sanded.
[3]This ratio is used to convert plywood volume in M ft^2 of the specific thickness to M ft^2 on a 3/8-inch basis.

COMPOSITION BOARD

BOARD TYPES

A variety of wood composition boards have been developed and are now manufactured in North America. As a group, these panel products are manufactured from wood or other lignocellulosic fibers or particles to which adhesives and other materials may be added to impart the desired panel properties.

A very wide range of composition board products is theoretically possible depending on species, particle size, type and amount of adhesive, type and amount of other additives, fiber orientation, board thickness and density, and manufacturing methods and conditions. Two broad categories of boards are generally recognized, fibrous-felted and particleboards (Maloney, 1977).

Fibrous-Felted Board

This panel type is made primarily from interfelted lignocellulosic fibers, to which other materials may be added and consolidated under heat and pressure.

Traditional products belonging to this group are:

- hardboard [densities of 31 lb/ft^3 (497 kg/m^3) or more], and
- insulation board [densities between 10 and 31 lb/ft^3 (160 to 497 kg/m^3)].

More recently medium density fiberboard (MDF) has been developed, with a density of 31 to 50 lb/ft^3 (497-800 kg/m^3) and dry formed with the use of a synthetic adhesive.

Particleboard

This generic term is used for panels made from lignocellulosic materials in the form of discrete pieces or particles (as opposed to fibers) combined with synthetic resins under heat and pressure and may contain other additives.

A variety of boards of this type in a wide range of densities, referred to as particleboard or chipboard is used as furniture core and floor underlayment.

More recently, several new product types have emerged within the "particleboard" category. Thinboard is a thin particleboard distinguished by the continuous pressing process by which it is produced.

Waferboard is a type of particleboard composed of wafers of uniform length and thickness resembling small pieces of veneer, with exterior bond quality, and intended for structural applications. Oriented strandboard (OSB) is another structural board in which long, narrow particles or strands of wood are aligned in the surface layers parallel to the length of the board, and the core is either randomly oriented or aligned at 90° to the particle direction on the surfaces. Both waferboard and OSB are made mainly in board densities of 40 to 45 lb/ft^3 (640 to 720 kg/m^3).

GREEN WOOD REQUIREMENTS

The volume of green wood required per unit of product output depends on many factors, but can be estimated using the following two general equations for imperial and metric units respectively.

Imperial Equation

I = input of green wood in ft^3 SWE per M ft^2 of board output:

$$I = \left[\left(\frac{1000\ t}{12\ w} \cdot \frac{d\ (1-MC-a)}{(1-s-k)}\right) \cdot \frac{1}{(1-v)}\right] \cdot \frac{1}{(1-f)}$$

Metric Equation

I = input of green wood in m^3 SWE per m^3 of board output.

$$I = \left[\left(\frac{d}{w} \cdot \frac{1-MC-a}{1-s-k}\right) \cdot \frac{1}{1-v}\right] \cdot \frac{1}{1-f}$$

where t = board thickness in inches
w = species density (o.d.) in lb/ft^3 or kg/m^3
d = board density in lb/ft^3 or kg/m^3
MC = board moisture content in percent of original-weight
a = additives as a proportion of product weight
s = sander waste as a proportion of input weight
k = trim waste as a proportion of input weight
v = volumetric shrinkage as a proportion of input volume
f = miscellaneous fiber loss as a proportion of input volume

The above formulas have been used to estimate green wood requirements for the various products over a range of wood and board densities (Tables 38 and 39). Values assumed for other variables fall within the range of those occurring in industrial practice today. For specific situations, alternate values may be required to make reasonable estimates of green wood requirements.

It is further noted that these panel products are made from sawmill and plywood plant residues, with the exception of waferboard and OSB. The latter two boards are produced from roundwood, and considerably larger wood fiber losses are incurred in their manufacture.

PANEL VOLUME MEASURES

Panel board thicknesses in inches and their metric equivalents are shown in Table 40.

A variety of units are currently used to measure volumes of panel products. Factors which can be used to convert between cubic and surface measures of panel volumes are provided in Table 41. The surface coverage of various densities and thicknesses of panels per short ton and per metric tonne are provided in Table 42.

Table 38

Green Wood Requirement Per M Square Feet of Board Production

Board Type and Process Variables	Wood Density (lb/ft^3)	Board Density (lb/ft^3)	Wood Input (ft^3/M ft^2)	Wood Input (ft^3/ton)
Hardboard (1/8-inch)	24	50	24.83	95.4
m.c. = .08 s = 0	24	60	29.80	95.4
v = .08 k = .10	28	50	21.28	81.7
a = .02 f = .05	28	60	25.54	81.7
Insulation Board (1/2-inch)	24	20	33.99	81.6
m.c. = .08 s = 0	24	30	50.98	81.6
v = .08 k = .10	28	20	29.13	69.9
a = .15 f = 0.5	28	30	43.70	69.9
Particleboard (5/8-inch)	24	40	97.58	93.7
m.c. = 0.6 s = .06	24	50	121.97	93.7
v = .08 k = .10	28	40	83.64	80.3
a = .08 f = .01	28	50	104.55	80.3
MDF (5/8-inch)	24	40	98.43	94.5
m.c. = .06 s = .06	24	45	110.73	94.5
v = .08 k = .10	28	40	84.37	81.0
a = .09 f = .03	28	45	94.91	81.0
Waferboard (3/8-inch)	24	40	73.12	117.0
m.c. = .04 s = 0	24	45	82.26	117.0
v = .08 k = .10	28	40	62.68	100.3
a = .03 f = .20	28	45	70.51	100.3
OSB (3/8-inch)	24	40	70.77	113.2
m.c. = .04 s = 0	24	45	79.61	113.2
v = .08 k = .10	28	40	35.38	56.6
a = .06 f = .20	28	45	39.81	56.6

Note: Key to process variables shown under "Green Wood Requirements".

Table 39

Green Wood Requirement Per Cubic Metre of Board Production

Board Type and Process Variables	Wood Density (kg/m^3)	Board Density (kg/m^3)	Wood Input (m^3/m^3)	Wood Input (m^3/tonne)
Hardboard	350	800	2.62	3.27
m.c. = .08 s = 0	350	1000	3.27	3.27
v = .08 k = .10	450	800	2.03	2.54
a = .02 f = .05	450	1000	2.54	2.54
Insulation Board	350	300	0.84	2.80
m.c. = .08 s = 0	350	450	1.26	2.80
v = .08 k = .10	450	300	0.65	2.17
a = .15 f = .05	450	450	0.98	2.17
Particleboard	350	650	2.09	3.21
m.c. = .06 s = .06	350	800	2.57	3.21
v = .08 k = .10	450	650	1.62	2.50
a = .08 f = .01	450	800	2.00	2.50
MDF	350	650	2.11	3.24
m.c. = .06 s = .06	350	750	2.43	3.24
v = .08 k = .10	450	650	1.64	2.52
a = .09 f = .03	450	750	1.89	2.52
Waferboard	350	640	2.57	4.01
m.c. = .04 s = 0	350	700	2.81	4.01
v = .08 k = .10	450	640	2.00	3.12
a = .03 f = .20	450	700	2.18	3.12
OSB	350	640	2.48	3.88
m.c. = .04 s = 0	350	700	2.72	3.88
v = .08 k = .10	400	640	2.17	3.40
a = .06 f = .20	400	700	2.38	3.40

Note: Key to process variables shown under "Green Wood Requirements".

Table 40

Board Thicknesses

inches	mm	inches	mm
1/8	3.2	9/16	14.3
3/16	4.8	5/8	15.9
1/4	6.4	11/16	17.5
3/8	9.5	3/4	19.1
7/16	11.1	7/8	22.2
1/2	12.7	1	25.4

Table 41

Conversion of Various Panel Volume Measures

Product and Unit	Cubic Metres	Cubic Feet	1,000 Board Feet
Surface Measures			
1,000 m^2 (1 mm basis)	1	35.315	0.424
1,000 ft^2 (1/8 in basis)	0.295	10.417	0.125
1000 ft^2 (3/8 in basis)	0.885	31.25	0.375
1000 ft^2 (1/2 in basis)	1.180	41.667	0.5
1000 ft^2 (5/8 in basis)	1.475	52.083	0.625

Table 42

Surface Measure of Panels Per Ton and Per Metric Tonne

Board Density	Panel Thickness			
	1/8 inch	3/8 inch	1/2 inch	5/8 inch
	(M ft^2 per ton)			
10 lb/ft^3	-	-	4.80	-
20 " "	-	-	2.40	-
30 " "	-	-	1.60	1.28
40 " "	4.80	1.60	-	0.96
45 " "	4.27	1.42	-	0.85
50 " "	3.84	1.28	-	0.77
55 " "	3.49	-	-	0.70
60 " "	3.20	-	-	-
70	2.74	-	-	-

	3.2 mm	9.5 mm	12.7 mm	15.9 mm
	(m^2 per tonne)			
300 kg/m^3	-	-	262.5	-
400 " "	-	-	196.8	-
450 " "	-	-	175.0	-
500 " "	-	-	-	125.8
600 " "	-	-	-	104.8
640 " "	-	-	-	98.3
650 " "	480.8	161.9	-	96.8
700 " "	446.4	150.4	-	89.8
800 " "	390.6	131.6	-	78.6
1000 " "	312.5	-	-	-
1200 " "	-	-	-	-

PULP

PULP YIELDS FROM WESTERN SPECIES

The yield of unbleached kraft pulp from pulp chips is estimated at the percentages shown in Table 43. Yields from sawdust and planer shavings are about two percent lower.

Mechanical pulp yields vary somewhat, depending on the specific process. Typical pulp yields for the most commonly employed processes are listed below.

	Yield (%)
stone groundwood pulp	95
refiner mechanical pulp	94 - 95
thermomechanical pulp	92 - 94
chemimechanical pulp	88 - 93

GREEN WOOD REQUIREMENTS PER TON (TONNE) OF PULP

Based on the pulp yields in Table 43 and the wood density for the species (Table 8), green wood requirements per short ton and per metric tonne of pulp would be as indicated in Table 44.

Chip volume requirements in volumetric units per short ton and metric tonne of pulp output are species-dependent. Estimated requirements are shown in Table 45.

Chip volume requirements in BDU per short ton or metric tonne of pulp output are independent of species density. Estimated chip requirements in BDUs are directly dependent on pulp yield as shown in Table 46.

Table 43

Unbleached Kraft Pulp Yields

Species	Yield (percent o.d. wood)
	Kappa No. 30
Cedar, western red	41
Cypress, yellow	41
Douglas-fir	45
Fir, alpine	44
Fir, amabilis	45
Hemlock, western	45
Larch, western	40
Pine, lodgepole	44
Pine, western white	45
Pine, ponderosa	45
Spruce, western	48
	Kappa No. 17
Alder, red	50
Aspen, trembling	55
Birch, white	53
Cottonwood, black	54
Maple, broadleaf	48

Source: Data from the late J.L. Keays, Western Forest Products Laboratory, and J.V. Hatton, Pulp and Paper Research Institute of Canada.

Table 44

Green Wood Requirements for Pulp Production

Species	Kraft Pulp[1]				Mechanical Pulp[1, 3]	
	Unbleached		Bleached[2]			
	ft^3/ short ton	m^3/ tonne	ft^3/ short ton	m^3/ tonne	ft^3/ short ton	m^3/ tonne
Cedar, western red	214	6.68	277	7.09	92	2.88
Cypress, yellow	168	5.24	179	5.57	72	2.26
Douglas-fir	142	4.43	152	4.74	67	2.11
Fir, alpine	199	6.22	212	6.62	92	2.88
Fir, amabilis	170	5.31	181	5.65	81	2.51
Hemlock, western	152	4.74	161	5.03	72	2.24
Larch, western	160	5.00	170	5.32	67	2.11
Pine, lodgepole	160	5.00	171	5.32	74	2.32
Pine, western white	181	5.65	192	6.00	86	2.67
Pine, ponderosa	165	5.15	176	5.49	78	2.44
Spruce, western	167	5.21	178	5.56	84	2.63
Alder, red	155	4.83	164	5.13	81	2.54
Aspen, trembling	140	4.38	149	4.66	81	2.53
Birch, white	108	3.36	114	3.57	60	1.87
Cottonwood, black	158	4.93	168	5.25	90	2.80
Maple, broadleaf	129	4.03	137	4.28	65	2.03

[1] Air dry pulp at 10 percent MC

[2] Assumes 6 percent loss in bleaching

[3] Assumes 95 percent yield

Table 45

Volumetric Units[1] of Chips Required for Pulp Production

Species	Kraft Pulp				Mechanical Pulp	
	Unbleached		Bleached[2]			
	GPU/ton	GPU/tonne	GPU/ton	GPU/tonne	GPU/ton	GPU/tonne
Cedar, western red	2.67	2.95	2.84	3.13	1.15	1.27
Cypress, yellow	2.10	2.32	2.24	2.47	0.90	0.99
Douglas-fir	1.77	1.96	1.90	2.09	0.84	0.92
Fir-alpine	2.49	2.74	2.65	2.92	1.15	1.27
Fir, amabilis	2.12	2.34	2.26	2.49	1.01	1.12
Hemlock, western	1.90	2.09	2.01	2.22	0.90	0.99
Larch, western	2.00	2.21	2.13	2.34	0.84	0.92
Pine, lodgepole	2.00	2.21	2.14	2.36	0.93	1.02
Pine, western white	2.26	2.49	2.40	2.65	1.08	1.19
Pine, ponderosa	2.06	2.27	2.20	2.43	0.98	1.07
Spruce, western	2.09	2.30	2.36	2.60	1.05	1.16
Alder, red	1.94	2.14	2.05	2.26	1.01	1.12
Aspen, trembling	1.75	1.93	1.86	2.05	1.01	1.12
Birch, white	1.35	1.49	1.42	1.57	0.75	0.83
Cottonwood, black	1.97	2.18	2.10	2.31	1.12	1.24
Maple, broadleaf	1.61	1.78	1.71	1.89	0.81	0.90

[1]A volumetric unit or "gravity packed unit" (GPU) of chips occupying 200 ft^3 of space is assumed to contain 80 ft^3 of solid wood.

[2]Assumes: - air dry pulp at 10 percent MC
- 6 percent loss in bleaching Kraft pulp
- mechanized pulp yield at 95 percent.

Table 46

Bone-Dry Units of Chips Required for Pulp Production

Kraft Pulp Yield	BDU/ ton	BDU/ tonne	Mechanical Pulp Yield	BDU/ ton	BDU/ tonne
37	2.03	2.23	90	0.83	0.92
38	1.97	2.18	91	0.82	0.91
39	1.92	2.12	92	0.82	0.90
40	1.88	2.07	93	0.81	0.89
41	1.83	2.02	94	0.80	0.88
42	1.79	1.97	95	0.79	0.87
43	1.74	1.92			
44	1.70	1.88			
45	1.67	1.84			
46	1.63	1.80			
47	1.60	1.76			
48	1.56	1.72			
49	1.53	1.69			
50	1.50	1.65			
55	1.36	1.50			

Basis:

a) A bone-dry unit contains 2,400 lb of wood, oven dry.
b) Assumes air dry pulp at 10 percent MC.

SHINGLES AND SHAKES

SHINGLE AND SHAKE SIZES AND UNITS OF MEASURE

The shingle and shake industry is now producing products in metric sizes which represent soft conversions from the imperial measurement system. The standard lengths and thicknesses are shown in Tables 47 and 48. Most shingles and shakes are produced in random widths.

The basic measurement unit for shingles and shakes in both imperial and metric is the "bundle". A bundle contains a specified number of courses of shingle or shake butts at each end of the bundle (Tables 47 and 48). A bundle contains sufficient shingles or shakes to cover specified areas per bundle for given exposures. Shingle and shake coverage in square metres per bundle are shown in Tables 49 and 50.

Traditionally, shingles and shakes have been sold by the "square", a volume which, by definition, covered 100 ft^2 of surface at specified exposures. For shingles, there are four bundles per square and for shakes, five bundles per square. The square is still used for most export shipments and to record industry production.

SHINGLE, SHAKE, AND RESIDUE YIELDS

The cubic volume of a bundle and product yields per unit of log input are shown in Tables 51 and 52 for shingles and shakes, respectively. Approximate proportions of the log converted to residues are as follows:

	Shingles (%)	Shakes (%)
Chips	27	27
Sawdust	33	23
Bark	6	6
Hog fuel (sawdust and bark)	39	29

Table 47

Red Cedar Shingle Sizes

Grade	Length			Thickness at Butt		No. of courses per bundle
	mm	inches		mm	inches	
No. 1 Blue Label	400	16	(Fivex)	10	.40	20/20
	450	18	(Perfections)	11	.45	18/18
	600	24	(Royals)	13	.50	13/14
No. 2 Red Label	400	16	(Fivex)	10	.40	20/20
	450	18	(Perfections)	11	.45	18/18
	600	24	(Royals)	13	.50	13/14
No. 3 Black Label	400	16	(Fivex)	10	.40	20/20
	450	18	(Perfections)	11	.45	18/18
	600	24	(Royals)	13	.50	13/14
No. 4 Undercoursing	400	16	(Fivex)	10	.40	14/14 or 20/20
	450	18	(Perfections)	11	.50	14/14 or 18/18
No. 1 or No. 2 Rebutted - Rejointed	400	16	(Fivex)	10	.40	33/33
	450	18	(Perfections)	11	.45	28/28
	600	24	(Royals)	13	.50	13/14

Source: Council of Forest Industries of British Columbia, 1975.

Table 48

Red Cedar Handsplit Shake Sizes

Grade	Type	Length and Thickness (mm)	Length and Thickness (inches)	No. of courses per bundle 465 mm (18 inch) pack
No. 1 Handsplit and Resawn	Starter-Finish Course	380	15	9/9
	Medium Resawn	450 x 13	18 x 1/2	9/9
	Heavy Resawn	450 x 19	18 x 3/4	
	Handsplit	600 x 9	24 x 3/8	9/9
	Medium Resawn	600 x 13	24 x 1/2	9/9
	Heavy Resawn	600 x 19	24 x 3/4	9/9
No. 1 Tapersplit	Tapersplit	600 x 13	24 x 1/2	9/9
No. 1 Straight-Split	True-Edge[1]	450 x 9	18 x 3/8	14 Straight[2]
	Straight-Split	450 x 9	18 x 3/8	19 Straight[2]
	Straight-Split	600 x 9	24 x 3/8	16 Straight[2]

[1]Exclusively sidewall product with parallel edges
[2]Packed in 505 mm (20 inch) wide frames

Source: Council of Forest Industries of British Columbia, 1975.

Table 49

Approximate Shingle Coverage (m^2/bundle)

Weather Exposures (mm)	Shingle Length and Thickness (mm)		
	400 x 10	450 x 11	600 x 13
90	1.69	1.52	1.14
100	1.88	1.69	1.27
115	2.16	1.95	1.46
125	2.35[1]	2.11	1.59
140	2.63	2.37[1]	1.78
150	2.82	2.54	1.90
165	3.10	2.79	2.09
180	3.38	3.04	2.28
190	3.57[3]	3.21	2.41[1]
200	3.76	3.38	2.54
215	4.04	3.64[3]	2.73
225	4.23	3.81	2.85
240	4.51	4.06	3.04
250	4.70	4.23	3.17
265	4.98	4.48	3.36
280	5.26	4.74	3.55
290	5.45	4.90	3.68[3]
305	5.73[2]	5.16	3.87
315	-	5.33	4.00
330	-	5.58	4.19
340	-	5.75	4.31
355	-	6.00[2]	4.50
365	-	-	4.63
380	-	-	4.82
390	-	-	4.95
405	-	-	5.14[2]

[1]Maximum exposure recommended for roofs.
[2]Maximum exposure for double-coursing No. 1 grade on sidewalls
[3]Maximum exposure recommended for single-coursing No. 1 and No. 2 grade on sidewalls.

Note: For dry shingles, reduce coverage by three percent for shrinkage.

Source: Canadian Wood Council, 1978.

Table 50

Shakes Coverage (m^2/bundle)

Shake Size Length and Thickness	Approximate coverage in m^2 of one bundle of handsplit shakes based on the following weather exposures											
	140 mm	165 mm	180 mm	190 mm	200 mm	215 mm	250 mm	290 mm	330 mm	355 mm	380 mm	405 mm
450 x 13 mm medium resawn	102[1]	1.21	1.32	1.39[2]	1.46	1.57[6]	1.83	2.12	2.41	2.60[4]	-	-
450 x 19 mm heavy resawn	1.02[1]	1.21	1.32	1.39[2]	1.46	1.57[6]	1.83	2.12	2.41	2.60[4]	-	-
600 x 9 mm handsplit	-	1.21	1.32	1.39[3]	1.46	1.57	1.83[5]	2.12[6]	-	-	-	-
600 x 13 mm medium resawn	-	1.21	1.32	1.39[1]	1.46	1.57	1.83[2]	2.12[6]	2.41	2.60	2.78	2.96
600 x 19 mm heavy resawn	-	1.21	1.32	1.39[1]	1.46	1.57	1.83[2]	2.12[6]	2.41	2.60	2.78	2.96
600 x 13 mm tapersplit	-	1.21	1.32	1.3[1]9	1.46	1.57	1.83[2]	2.12[6]	2.41	2.60	2.78	2.96
450 x 9 mm true-edge-straight-split	-	-	-	-	-	-	-	-	-	2.27	2.43	2.59[4]
450 x 9 mm straight-split	1.22[1]	1.43	1.56	1.65[1]	1.74	1.87[6]	2.17	2.52	2.87	3.08	3.30	3.52[4]
600 x 9 mm straight-split	-	1.21	1.32	1.39[1]	1.46	1.57	1.83	2.12	2.41	2.60	2.78	2.96
300 mm starter-finish course	Use supplementary with shakes applied not over 250 mm weather exposure.											

[1]Maximum exposure recommended for 3-ply roof construction.
[2]Maximum exposure recommended for 2-ply roof construction.
[3]Maximum exposure recommended for roof pitches of 18° to 33.5°.
[4]Maximum exposure recommended for double-coursing on sidewalls.
[5]Maximum exposure recommended for roof pitches of 33.5° or steeper.
[6]Maximum exposure recommended for single-coursing on sidewalls.

Source: Metric Manual for Wood Products, Canadian Wood Council, 1978.

Table 51

Volume Content and Log Volume Requirements for Red Cedar Shingles

Shingle Type	m^3 per bundle[1]	ft^3 per bundle	Bundles per m^3 log[2]	Bundles per cunit[2]
Fivex	.0432	1.53	9.26	26.22
Perfection	.0477	1.68	8.39	23.76
Royal	.0557	1.97	7.18	20.33
Undercourse:				
400 mm (16 inches)	.0299	1.06	13.38	37.89
450 mm (18 inches)	.0378	1.33	10.58	29.96
600 mm (24 inches)	.0526	1.86	7.60	21.52

Source: [1]Canadian Forest Products Ltd., Vancouver, B.C.

[2]Based on recovery of 40 percent of log volume.

Table 52

Volume content and Log Volume Requirements for Red Cedar Shakes

Shake Type	Size (mm)	Size (inches)	m^3 per Bundle	ft^3 per Bundle	Bundles per m^3 log[1]	Bundles per cunit[1]
Heavy resawn	600 x 19	24 x 3/4	.0524	1.85	9.54	27.01
	450 x 19	18 x 3/4	.0444	1.57	11.26	31.88
Medium resawn	600 x 13	24 x 1/2	.0474	1.67	10.55	29.87
	450 x 13	18 x 1/2	.0355	1.25	14.08	39.87
Straight split	600 x 9	24 x 3/8	.0382	1.35	13.09	37.07

[1]Based on recovery of 50 percent of log volume.

ENERGY

HIGHER HEATING VALUES OF WOOD AND BARK

Higher heating values of wood and bark fuels are expressed in British thermal units per pound (BTU/lb) or megajoules per kilogram (MJ/kg). Heating values for o.d. wood and bark for the most common western Canadian species are provided in Table 53. Heat values per unit of wood weight do not vary greatly between species. However, when expressed on a volume basis the heating value of wood varies more widely due to the effect of species density, as shown in Table 54. In general, dense species provide higher heating values per unit of volume than less dense species.

BURNING EFFICIENCY AND MOISTURE CONTENT

Losses associated with the burning of wood reduce the recoverable heat below that shown in the above tables. These losses primarily reflect the efficiency of the burner system, the humidity of the combustion air, and the moisture content of the wood. Using the wood fuel value calculation methods outlined by Curtis (1976), o.d. wood has a burning efficiency of about 80 percent. As moisture content increases, burning efficiency decreases, as does the net usable heat (Table 55). These values should be used as approximations only, being dependent on assumptions concerning heat loss calculations. Ince (1979) has outlined a more detailed method of estimating recoverable heat accounting for: the effects of moisture, the effects of hydrogen in the fuel, heat lost via dry gas and excess air, and conventional heat loss.

HEATING VALUES FOR FOSSIL FUELS

The energy contents and approximate industrial burning efficiencies of some common fossil fuels are provided in Table 56 for comparison.

AVAILABLE HEAT IN HOG FUEL

The heat available from burning hog fuel depends largely on the combined effects of species, proportions of wood and bark, and the moisture content of individual components of the fuel mix (bark, sawdust, shavings). Estimated gross heating values for various hog fuel mixtures are given in Table 57. Recoverable heat can be estimated by multiplying these values by the appropriate "% of higher heating value" in Table 55 if the average moisture content of the fuel is known.

Table 53

Higher Heating Values for Wood and Bark

Species	Wood		Bark	
	BTU/lb	MJ/kg	BTU/lb	MJ/kg
Cedar, western red	9700	22.56	8700	20.24
Cypress, yellow	9900	23.03	-	-
Douglas-fir	9200	21.40	10100	23.49
Fir, balsam	8616[3]	20.04	8861-9338[3]	20.61-21.72
Fir (unspecified)	8300[1]	19.31	9100[2]	21.17
Hemlock, western	8500	19.77	9800	22.79
Larch, western	8371-8693[3]	19.47-20.22	8203-10241[3]	19.08-23.82
Pine, jack	8340-8663[3]	19.40-20.15	8689-9394[3]	20.21-21.85
Pine, lodgepole	8600	20.00	10760[1]	25.03
Pine, ponderosa	9100	21.17	9616[2]	22.37
Spruce, black	-	-	8610-9143[2]	20.03-21.27
Spruce, Sitka	8100	18.84	-	-
Spruce, white	8504[3]	19.78	8530-8912[3]	19.84-20.73
Alder, red	8000	18.61	8410[1]	19.56
Aspen, trembling	8319-8904[3]	19.35-20.71	8435-8710[3]	19.62-20.26
Birch, white	9340	21.72	9887-10332[2]	23.00-24.03
Cottonwood, black	8800	20.47	9000[1]	20.93
Maple, broadleaf	8400	19.54	-	-
Poplar (unspecified)	8311-8920[4]	19.33-20.75	8810[4]	20.49

Sources:

[1]Corder, 1973
[2]Ince, 1979
[3]Kryla, 1984
[4]Arola, 1976

Other data from: Guernsey, 1959, and information on file at Forintek Canada Corp., Western Laboratory

Metric data soft-converted from imperial units.

Table 54

Higher Heating Values Per Unit Volume[1]

Species	Million BTU/cord[2]	Million BTU/GPU[3]	MJ/m^3
Cedar, western red	16.927	14.537	7422
Cypress, yellow	22.005	18.899	9650
Douglas-fir	21.959	18.859	9630
Fir, alpine	14.484	12.439	6353
Fir, amabilis	16.593	14.251	7280
Fir, balsam	15.306	13.145	6713
Hemlock, western	19.074	16.381	8363
Larch, western	20.364	17.489	8930
Pine, jack	18.983	16.303	8325
Pine, lodgepole	18.655	16.021	8180
Pine, ponderosa	18.726	16.083	8214
Spruce, Sitka	14.906	12.802	6537
Spruce, white	16.235	13.943	7121
Alder, red	15.830	13.596	6942
Aspen, trembling	17.084	14.672	7491
Birch, white	25.063	21.525	10990
Cottonwood, black	15.783	13.555	6919
Maple, broadleaf	20.763	17.832	9106
Poplar, balsam	15.407	13.232	6774

[1]Based on wood only, in oven-dry condition
[2]Based on 85 ft^3 SWE/cord
[3]Based on 73 ft^3 SWE/GPU

Table 55

Effect of Moisture Content on Recoverable Heat
Per lb or kg of Wet Wood

Moisture Content (o.w. basis)	Industrial Burner Efficiency %	Net Usable Heat		
		MJ/kg	BTU/lb	% of higher heating value
0	80	16.00	6880	80
10	78.5	14.13	6076	71
20	76.5	12.24	5263	61
30	74	10.36	4455	52
40	72	8.64	3715	43
50	67	6.70	2881	33

Basis:

a) Estimated using the method outlined by Curtis, 1978.
b) Assumed higher heating value of 20.00 MJ/kg or 8600 BTU/lb.
c) One pound or one kilogram (wet wood) = (wood weight) + (water weight).

Table 56

Energy Content of Conventional Fuels

Fuel Type	Units	Energy (million BTU)	Industrial Conversion Efficiency (%)
Coal:			87
Anthracite	ton	25.4	
Can. Bituminous	"	25.2	
Subbituminous	"	17.0	
Lignite	"	13.2	
LPG	barrel	4.095	85
Crude Oil	"	5.803	
Light fuel oil	"	5.827	82
Heavy fuel oil	"	6.287	87
Natural gas	1,000 ft^3	1.0 - 1.07	85
Electricity	1,000 kwh	3.412	100

Source: Canada Dept. Energy, Mines and Resources, 1977.

Table 57

Heat Available in Hog Fuel (oven dry)

Species	Percentage Bark Content					
	40	60	40	60	40	60
	BTU/lb		Million BTU/GPU		Million BTU/BDU	
Douglas-fir	9560	9740	20.41	21.21	22.94	23.38
Western hemlock	9020	9280	19.38	20.97	21.65	22.27
Western red cedar	9300	9100	14.07	13.83	22.32	21.84
Lodgepole pine	9464	9896	19.70	21.68	22.71	23.75
White spruce	8590	8635	15.47	16.25	20.62	20.72
	MJ/kg		MJ/m^3		GJ/tonne	
Douglas-fir	22.24	22.66	3806	3955	22.24	22.66
Western hemlock	20.98	21.59	3613	3910	20.98	21.59
Western red cedar	21.63	21.17	2620	2575	21.63	21.17
Lodgepole pine	22.01	23.02	3671	4042	22.01	23.02
White spruce	19.98	20.08	2885	3030	19.98	20.08

Basis:

[1]Higher heating values for wood and bark from Table 53.

[2]Wood and bark densities from Tables 8 and 17 respectively.

[3]A gravity packed unit (GPU) contains 73 ft^3 solid wood equivalent.

[4]One cubic metre of gravity packed hog fuel contains 0.365 m^3 solid wood equivalent.

[5]One gigajoule (GJ) = 10^9 joules.

MISCELLANEOUS

Saw Gauges
Decimal Equivalents
Metric Prefixes
Metric Conversion Factors
Some Geometric Formulas
Botanical Names of Western Tree Species

Table 58

Saw Gauges (By Thousands)

Gauge (Birmingham)	Fraction Inch		Thousandths Inch	Millimetres
	1		1.000	25.40
	7/8		.875	22.225
	3/4		.750	19.05
	5/8		.625	15.875
	1/2		.500	12.70
	15/32		.46875	11.905
0000	29/64		.454	11.53
000	27/64	Full	.425	10.79
00	3/8	Full	.380	9.65
0	11/32	Scant	.340	8.64
1	5/16	Scant	.300	7.62
2	9/32		.284	7.21
3	1/4	Full	.259	6.57
4	15/64		.238	6.04
5	7/32		.220	5.59
6	13/64		.203	5.18
7	3/16	Scant	.180	4.57
8	5/32	Full	.165	4.19
9	5/32	Scant	.148	3.76
10	1/8	Full	.134	3.40
11	1/8	Scant	.120	3.05
12	7/64		.109	2.77
13	3/32		.095	2.41
14	5/64	Full	.083	2.10
15	5/64	Scant	.072	1.82
16	1/16	Full	.065	1.65
17	1/16	Scant	.058	1.47
18	3/64		.049	1.24
19	-		.042	1.06
20	-		.035	.89
21	1/32		.032	.81
22	-		.028	.71
23	-		.025	.64
24	-		.022	.56
25	-		.020	.51
26	-		.018	.46
27	1/64		.016	.41
28	-		.014	.36
29	-		.013	.33
30	-		.012	.30

Source: Quelch, P.S. 1970. Armstrong Saw Filer's Handbook. Armstrong Manufacturing Co., Portland, Oregon.

Table 59

Decimal Equivalents

1/64	=	.016	33/64	=	.516
1/32	=	.031	17/32	=	.531
3/64	=	.047	35/64	=	.547
1/16	=	.063	9/16	=	.563
5/64	=	.078	37/64	=	.578
3/32	=	.094	19/32	=	.594
7/64	=	.109	39/64	=	.609
1/8	=	.125	5/8	=	.625
9/64	=	.141	41/64	=	.641
5/32	=	.156	21/32	=	.656
11/64	=	.172	43/64	=	.672
3/16	=	.188	11/16	=	.688
13/64	=	.203	45/64	=	.703
7/32	=	.219	23/32	=	.719
15/64	=	.234	47/64	=	.734
1/4	=	.250	3/4	=	.750
17/64	=	.266	49/64	=	.766
9/32	=	.281	25/32	=	.781
19/64	=	.297	51/64	=	.797
5/16	=	.313	13/16	=	.813
21/64	=	.328	53/64	=	.828
11/32	=	.344	27/32	=	.844
23/64	=	.359	55/64	=	.859
3/8	=	.375	7/8	=	.875
25/64	=	.391	57/64	=	.891
13/32	=	.406	29/32	=	.906
27/64	=	.422	59/64	=	.922
7/16	=	.438	15/16	=	.938
29/64	=	.453	61/64	=	.953
15/32	=	.469	31/32	=	.969
31/64	=	.484	63/64	=	.984
1/2	=	.500			

Table 60

Metric Prefixes With Exponent Values

Prefix	Symbol	SI Prefixes Factor by which the unit is multiplied	Exponent
exa	E	1 000 000 000 000 000 000	$= 10^{18}$
peta	P	1 000 000 000 000 000	$= 10^{15}$
tera	T	1 000 000 000 000	$= 10^{12}$
giga	G	1 000 000 000	$= 10^{9}$
mega	M	1 000 000	$= 10^{6}$
kilo	k	1 000	$= 10^{3}$
hecto	h	100	$= 10^{2}$
deca	da	10	$= 10^{1}$
		1	$= 10^{0}$
deci	d	0.1	$= 10^{-1}$
centi	c	0.01	$= 10^{-2}$
milli	m	0.001	$= 10^{-3}$
micro	μ	0.000 001	$= 10^{-6}$
nano	n	0.000 000 001	$= 10^{-9}$
pico	p	0.000 000 000 001	$= 10^{-12}$
femto	f	0.000 000 000 000 001	$= 10^{-15}$
atto	a	0.000 000 000 000 000 001	$= 10^{-18}$

Table 61

Metric Conversion Factors

Length

1 mm (millimetre) = 0.039 370 1 inch	1 in (inch) = 25.4 mm (exactly)
1 m (metre) = 3.280 84 feet	1 ft (foot) = 0.304 8 m (exactly)
1 m (metre) = 1.093 61 yards	1 yd (yard) = 0.914 4 m (exactly)
1 km (kilometre) = 0.621 371 mile	1 mi (mile) = 1.609 34 km

Area

1 cm^2 (square centimetre) = 0.155 000 square inch	1 in^2 (square inch) = 6.451 6 cm^2 (exactly)
1 m^2 (square metre) = 10.736 9 square feet	1 ft^2 (square foot) = 0.092 903 0 m^2
1 m^2 (square metre) = 1.195 99 square yards	1 yd^2 (square yard) = 0.836 127 m^2
1 ha (hectare) = 2.471 05 acres	1 acre = 0.404 686 ha

Volume

1 m^3 (cubic metre) = 35.314 7 cubic feet	1 ft^3 (cubic foot) = 0.028 316 8 m^3
1 m^3 (cubic metre) = 423.7 fbm (approx.)[1]	1,000 fbm (board feet) = 2.36 m^3 (approx.)[1]
1 m^3 (cubic metre) = 1.307 95 cubic yards	1 yd^3 (cubic yard) = 0.764 555 m^3
1 m^3 (cubic metre) = 0.353 147 cunit	1 cunit = 2.831 68 m^3
1 L (liter) = 0.219 969 gallon	1 gal. (gallon) = 4.546 09 L (exactly)

Mass

1 kg (kilogram) = 2.204 62 pounds	1 lb. (pound--avoirdupois) = 0.453 592 kg
1 t (tonne) = 1.102 31 tons (2,000 lb)	1 ton (2,000 lb) = 0.907 185 t

Heat

1 J (joule) = .0009478 BTU	1 BTU (British Thermal Unit) = 1055.06 J
1 MJ (megajoule) = .009478 therms	1 therm = 105.506 MJ

Ratios

1 kg/m^3 = 0.062428 lb/ft^3	1 lb/ft^3 =16.0185 kg/m^3
1 m^3/t = 32.037 ft^3/ton	1 ft^3/ton = 0.031214 m^3/t
1 m^3/ha = 14.2913 ft^3/acre	1 ft^3/acre = 0.0699725 m^3/ha
1 J/kg = 0.0004299 BTU/lb	1 BTU/lb = 2,326 J

[1]These are the conversion factors commonly used to convert gross volumes of softwood lumber. They are based on the volumetric ratio between one cubic metre (1 m x 1 m x 1 m) and one board foot (1 inch x 12 inch x 1 foot), with no variation between actual and nominal sizes.

Table 62

Some Geometric Formulas

1. Circle of radius r. Circumference = $2\pi r$. Area = πr^2

2. Circular sector. Area = $1/2 r^2 \alpha$, α being the central angle, measured in radians (π radians = 180°)

3. Trapezoid of height h and bases b and B. Area = $1/2 h (b + B)$

4. Right circular cylinder of height h, radius of base r.
Volume = $\pi r^2 h$. Lateral surface = $2\pi rh$.

5. Right circular cone of height h, radius of base r.
Volume = $1/3 \times \pi r^2 h$. Lateral surface = πrL.

$$\text{where } L = \sqrt{r^2 + h^2}$$

6. Frustum of a cone of height h, radius of top r_1, radius of base r_2, and slant length ℓ.

$$\text{Volume} = \frac{\pi h (r_1^2 + r_2^2)}{2}$$

$$\text{Lateral surface} = \pi (r_1 + r_2) \ell$$

7. Sphere of radius r. Volume = $4/3 \times \pi r^3$. Surface area = $4\pi r^2$

Table 63

Botanical Names for Some Western Canadian Tree Species

Common Name	Botanical Name	Recommended Symbol
Cedar, eastern white[1]	Thuja occidentalis L.	EWC
Cedar, western red	Thuja plicata Donn.	WRC
Cypress, yellow	Chamaecyparis nootkatensis (D. Don) Spach	CY
Douglas-fir	Pseudotsuga menziesii (Mirb.) Franco	DF
Fir, alpine	Abies lasiocarpa (Hook.) Nutt.	ALF
Fir, amabilis	Abies amabilis (Dougl.) Forbes	AF
Fir, balsam	Abies balsamea (L.) Mill.	BF
Hemlock, western	Tsuga heterophylla (Raf.) Sarg.	WH
Larch, western	Larix occidentalis Nutt.	WL
Pine, eastern white[1]	Pinus strobus L.	EWP
Pine, jack	Pinus banksiana Lamb.	JP
Pine, lodgepole	Pinus contorta Dougl.	LP
Pine, ponderosa	Pinus ponderosa Laws.	PP
Pine, red[1]	Pinus resinosa Ait.	RP
Pine, western white	Pinus monticola Dougl.	WWP
Spruce, black	Picea mariana (Mill.) B.S.P.	BS
Spruce, Engelmann	Picea engelmannii Parry	ES
Spruce, Sitka	Picea sitchensis (Bong.) Carr.	SS
Spruce, white	Picea glauca (Moench) Voss	WS
Spruce, western white	Picea glauca var. albertiana (S. Brown) Sarg.	WWS
Tamarack	Larix laricina (Du Roi) K. Koch	TL
Alder, red	Alnus rubra Bong. (Alnus oregona Nutt.)	AL
Ash, black[1]	Fraxinus nigra Marsh.	BAS
Ash, western green[1]	Fraxinus pennsylvanica var. subintegerrima (Vahl) Fern.	GAS
Basswood[1]	Tilia americana L.	BL
Birch, white	Betula papyrifera Marsh.	WB
Birch, western white	Betula papyrifera var. commutata (Reg.) Fern.	WW
Elm, white[1]	Ulmus americana L.	WE
Ironwood[1]	Ostrya virginiana (Mill.) K. Koch	-
Maple, broadleaf	Acer macrophyllum Pursh	BLM
Maple, Manitoba	Acer negundo L.	MM
Oak, bur	Quercus macrocarpa Michx.	BO
Poplar - trembling aspen	Poplus tremuloides Michx.	TA
Poplar - largetooth aspen	Populus grandidentata Michx.	LTA
Poplar - balsam	Populus balsamifera L.	BPO
Poplar - eastern cottonwood	Populus deltoides Bartr.	ECO
Poplar - black cottonwood	Populus trichocarpa Torr. and Gray	BCO

Source: Native Trees of Canada. 8th ed. Hosie, 1979.

[1]Ranges into southeastern Manitoba

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